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"The Spirit of St. Louis" just prior to its record-breaking flight from New York to Paris.

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EVERYONE knows, by this time, that Captain Lindbergh made careful preparations for his New York to Paris flight and that his success was not due to "luck." That Agathon Alloy Steels were used in the Wright Whirlwind Motor is only natural. These super-steels were selected for the crankshaft and cams, those important moving parts whose ability to stand up are a deciding factor in the success of an endurance flight. The crankshaft made over three million revolutions without falter or strain. Also the chrome molybdenum tubing used in the landing gear and engine was made from Agathon Alloy Steel by the Ohio Seamless Tube Company of Shelby, Ohio. This is the third time within a short period that Agathon Alloy Steels have stood the grueling grinds of history-making flights. They were used in the engines which propelled Captain Byrd over the North Pole and recently in the engines which kept the Bellanca plane aloft for over 51 hours to break the world's endurance record.

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TRANSACTIONS
American Society for Steel Treating

VOL. XII JULY, 1927 NO. 1

AN ESTABLISHED MODE OF TRAVEL

THE past two months has seen America definitely linked to Europe by the air, and America's dauntless aviators, Maitland and Hegenberger, forged connections with our western neighbors. The exploits of Lindbergh, Chamberlin, Byrd and Maitland have added much to the prowess of America.

The year 1927 is certain to be written large in the history of flying. Achievements like those which have been witnessed within the past sixty days lead to others. This is the history of time.

In the year 1919 the Atlantic was crossed four times through the air. Hawker's drop into the sea was followed by Alcock's successful jump from Newfoundland to Ireland. Shortly after the dirigible R-34 made a round trip flight from England to America.

With the stimulus which flying has had as the result of the Lindbergh flight to Paris, the present summer bids well to see greater distances covered and more lasting records established. With the development of better and more enduring airplanes and engines the confidence of daring aviators has been much stimulated and flights to Rome, Africa and Japan are the order of the day. Airplanes of today are vastly better than they were a few years back and no doubt the planes of tomorrow will be vastly better than those of today.

Lindbergh set the world aglow with enthusiasm for aeronautics by his single-handed victory over the laws of nature. Perhaps this could be better put by saying his single-handed victory through his knowledge of and compliance with the laws of nature. So great was his achievement that the Chamberlin-Levine flight came like an anti-climax and these Americans have been winging their way about Europe almost unnoticed by the world at large.

Though lacking in the dramatic appeal of the Lindbergh achievement, the Maitland-Hegenberger flight challenges the attention of the world. It has the appeal that always belongs to the first accomplishment in any field of useful endeavor. Such flights will no doubt become commonplace in time, but no later victory will detract from the glory of these achievements. A thousand men may hop off from New York to Paris or Hawaii, but the Lindbergh and Maitland-Hegenberger places are fixed in history. The flights which have recently been successfully negotiated are epochal in their importance and the fullest praise is due the intrepid pilots who have risked their lives in these useful adventures.

That flying would be a commonplace mode of travel was unthought of twenty-five years ago, but today it holds a fascinating and vastly important place in the welfare of mankind.

With the invention and development of the gasoline engine and then later the invention of the flying plane by the Wright brothers, marvelous developments have been made from the mechanical standpoint. Everyone remembers the day when the one-cylinder automobile chugged along the road and frequently got balky and "stalled". Likewise similar difficulties were experienced by those who put engines of much improved design into airplanes. Unfortunately failure to function while in the air often caused serious if not complete disaster for the flyer.

It is significant of the improvement which has been made in the design and construction of the latest modern airplane engines that in all of the long distance flights which have been made by Americans, the engines have performed perfectly. Chamberlin and Byrd were forced down because they were out of fuel but they report that their engines functioned marvelously and without faltering. This marks a great achievement in the art of engine design and manufacture, wherein the best brains of American and foreign engineers and mechanics have combined their knowledge in the production of an engine which is capable of continuous operation over several hundred hours. Much of this accomplishment can be attributed to the use of properly heat treated aluminum alloys and alloy steels. Therein does the art and science of metallurgy play a major role in the progress and development of the world.

IRON-CARBON-VANADIUM ALLOY FOR BRINELL BALLS*

By G. W. Quick and L. Jordan

Abstract

A special iron-carbon-vanadium alloy of about 2.9 per cent carbon and 13 per cent vanadium has been experimentally used for Brinell balls in the testing of steels of such hardnesses as cause ordinary Brinell balls to deform both elastically and plastically. These special balls, heat-treated, work-hardened, and tested against steels of approximately 700 Brinell, flattened about one-half as much as Hultgren balls and one-fifth as much as ordinary Brinell balls. The opinion that the hardness obtainable in a plain carbon steel by combined heat treatment and cold-work is the maximum hardness to be secured by such treatments, irrespective of the composition of the steel, is shown to be untrue. The difference in flattening between iron-carbon-vanadium and Hultgren balls does not, however, appreciably affect the hardness number of steels up to 700 Brinell.

I. Introduction

THE Brinell indentation test gives figures which within certain limits are roughly proportional to the tensile strength and endurance limit of steel. The harder the steel the more costly it is to prepare tensile and endurance specimens and the greater is the tendency to utilize the approximations obtainable through the medium of the cheap and rapid Brinell test.

But the Brinell testing of very hard steels is subject to errors and difficulties. Since the impressions are small, slight errors in the measurement of their average diameters markedly affect the accuracy of the Brinell numbers, and while it is customary to report them as, for example, 418 or 712, because the formula gives those figures for certain diameters of the impression, the precision of measurement and the roundness of the impression seldom, if ever, really justify the final digits. These errors can, however, be minimized by obvious means, in precision testing.

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A paper presented before the Winter Sectional Meeting of the Society, January 19 and 20, 1927 at Washington D. C. Of the authors G. W. Quick is assistant metallurgist and L. Jordan is chemist, Bureau of Standards, Washington, D. C.

Other difficulties, not so readily avoided, beset the use of the Brinell test on very hard steels. It is the purpose of this paper to describe experiments aimed toward the reduction of one of these difficulties, the permanent deformation or flattening of the Brinell ball. While this aim was attained, it should be stated at the outset that no marked increase has resulted in the precision of the Brinell test as applied to that class of steels for which increased precision is most needed.

From the literature of the subject one might have expected decidedly better Brinell tests to have resulted from the use of a ball decidedly less subject to permanent deformation.

Moore[1] points out that the correlation of Brinell hardness and endurance limit holds fairly well up to the point "where the Brinell test itself begins to be unsatisfactory on account of the deformation of the steel ball. This occurs at a Brinell number of about 400."

The work of Foss and Brumfield[2] shows a marked flattening of the ordinary ball when used on steels whose Brinell numbers are above 450.

Mailander[3] points out that the ball must be so hard that it takes no permanent deformation. By tempering ordinary balls at increasing temperatures so as to secure a series of increasing softness and making the Brinell test with them he shows that the ball should have a Brinell number at least 1.7 times that of the material being tested. In other words, his work indicates that to obtain the correct Brinell number of a 700 Brinell steel, the ball should have a Brinell number of 1200. He states that ordinary balls give correct figures only to 450, and work-hardened balls only to 500.

The chief error in Brinell testing hard steels is quite generally ascribed to the flattening of the ball. Batson[4] states that Brinell testing is unsatisfactory above 600 Brinell on account of ball-flattening. He suggests determination of hardness by means of refined measurement of the flattening produced upon the ball.

[1]Moore H. F.—An investigation of the fatigue of metals, Series of 1922, Univ. of Ill. Exp. Station Bull. No. 136, p. 55, 1923.

[2]Foss F. E. and Brumfield R. C.—Some measurements of the shape of Brinell ball indentation. Proceedings American Society for Testing Material, Vol. 22, Pt. II, p. 312, 1922.

[3]Mailander, R. Die Hartepruung von geharteten Stahlen. *Stahl und Eisen*, Vol. 45, 1925, p. 1769.

[4]Batson, R. G. C.—Static indentation tests—*Engineering*, Vol. 115, 1923, p. 534.

Petrenko[5] says, "In choosing a ball for the test, it should be remembered that even a small permanent deformation of the ball is likely to result in a considerable change in its radius of curvature at the spot in contact with the specimen and, consequently, in an appreciable error of hardness number."

German[6] says that "the ball must be sufficiently hard that it will not deform permanently in tests. If the ball deforms under load, it will flatten at the points of applied pressure and produce a shallow impression which will give an inaccurate reading."

The recognized effect of permanent flattening of the steel ball has led to several investigations in which diamond balls were used.

O'Neill[7] has stated that a steel of 100 scleroscope showing 670 Brinell with a steel ball (10 millimeters, 3000 kilograms), shows 875 with a diamond ball (1 millimeter, 30 kilograms), and that the steel ball flattened 0.03 millimeters or 0.0012 inch.

Mailander[8] used a 5-millimeter diamond ball loaded only to 187.5 kilograms instead of to the 750 kilograms required for geometric similarity of impression. With this low load the Brinell number of a certain steel was, with the diamond ball, a work hardened ball and an ordinary ball, (all of 5 millimeters diameter) respectively 600, 495, and 455. Mailander calculated the probable Brinell number with the diamond ball at 750 kilograms, and determined it with the 5 millimeters work hardened and ordinary steel balls, respectively, as 765, 710, and 665. By using the Meyer formula $p = ad^n$ which is explained by Hoyt,[9] Mailander plots the calculated hardness for different values of "n". On the steels tested "n" varied from 2.3 to 2.7 while the "n" for softer steels, according to Meyer and Hoyt, ranges from 2.15 to 2.35. The exponent "n" rises with increasing hardness of the steel tested. Since the harder the ball the lower the "n" for any given steel, Mailander concludes that "the harder the

[5]Petrenko, S. N.—Elastic Ring for Verification of Brinell Hardness Testing Machines. TRANSACTIONS American Society for Steel Treating, Vol. 9, 1926, p. 534.

[6]German, H. M.—Standardizing the Brinell Hardness Test. TRANSACTIONS, American Society for Steel Treating, Vol. 11, 1927, p. 54.

[7]O'Neill, H. Discussion. *Journal*, (British) Iron and Steel Institute, Vol. 113, 1926, p. 331.

[8]See reference 3.

[9]Hoyt, S. L.—The Ball Indentation Hardness Test. TRANSACTIONS, American Society for Steel Treating, Vol. 6, 1924, p. 396.

ball, the smaller its flattening and the smaller the apparent increase in "n"; the greater the diameter of the ball and the lower the pressure upon it, the smaller is the influence of flattening." Hence he concludes that "n" is best taken, for extrapolation of the 5-millimeter diamond ball tests to 750 kilograms at a value of 2.35 instead of 2.70 and thus he arrives at 765 as the extrapolated value for the Brinell number of his hardest steel (for the 5-millimeter diamond ball at 750 kilograms) against 710 for the work hardened ball. Were the value of 2.70 used for "n", the calculated value for the diamond ball would be 900.

Shore[10] used a 10-millimeter diamond ball under a load of 750 kilograms and on a steel of 105 scleroscope reading found a Brinell of 770, while an ordinary steel ball at the same load showed but 525. He states that errors of measurement of diameter of the impressions of a 10-millimeter ball on hard steels approach 75 points on the Brinell scale. On steel of 100 scleroscope, Shore got 680 Brinell with the 10-millimeter diamond ball at 750 kilograms.

Remembering that to get impressions geometrically similar to those at 3000 kilograms with a 10-millimeter ball the load on a 1-millimeter ball must be 30 kilograms and on a 5-millimeter ball 750 kilograms, it is seen that there are very few tests on record, made with diamond balls, that are directly comparable with those with 10-millimeter steel balls. Moreover, the smaller the ball the smaller the impression and the greater the error in measuring its diameter.

Hultgren[11] attacked the problem by increasing the hardness of the ball and hence decreasing its permanent deformation, through work-hardening.

By running ordinary heat treated balls in a ball bearing race at a load of 2200 kilograms per ball for 3 minutes at 1440 revolutions per minute or 2 minutes at 2000 revolutions per minute in a continuous stream of mineral oil Hultgren rendered these balls much more resistant to permanent flattening when used in the Brinell test against hard steel than they were in the simple heat treated condition. The balls were made of a 1.2 per cent

[10]Shore, A. F.—Report on hardness testing, *Journal* British Iron and Steel Institute, Vol. 98, 1918, p. 59.

[11]Hultgren, A.—Improvement in Brinell Tests on Hardened Steel Including a New Method of Producing Hard Steel Balls, *Journal*, Iron and Steel Institute 1924, Vol. 110, No. II. p. 183

carbon steel with no alloying elements. The races contained 8 balls so that the total load used, 3500 kilograms, was equivalent to a maximum of a 2200-kilogram load on each ball. A finger was arranged to bear against each ball when it passed the unloaded position in the race and to turn it to secure uniform cold working. This cold working decreased the permanent flattening of the ordinary 10-millimeter carbon steel balls from 0.038 millimeter (0.0015 inch) to 0.015 millimeter (0.0006 inch) when used in the Brinell test on a steel calculated to have a Brinell number of 735 when extrapolated corrections for ball-flattening are applied. The apparent Brinell number of the steel on which the balls were tested was about 670 with the ordinary ball, but rose to 710 with the work hardened ball. A special heat treated but unworked ball of American make containing 1.40 per cent carbon, 0.60 per cent chromium, 4.0 per cent tungsten, indicated a Brinell number of 675. On steel of 505 Brinell number, all the balls gave the same result, but as specimens of increasing hardness were tested the superiority of the cold-worked ball became greater. On the hardest steel tested, even this special ball gave results 3½ per cent lower than the value Hultgren obtained by using an extrapolated correction for flattening of the ball. Hultgren also work-hardened 1.2 per cent carbon steel balls which had been previously heat treated so as to secure a very fine grain, American chromium-tungsten balls, and balls containing 0.90 per cent carbon, 1.0 per cent chromium and 1.6 per cent silicon, but no superiority over the plain carbon balls with ordinary heat treatment was obtained in any case.

He states, "It seems therefore that superiority in hardness of certain balls of special composition or heat treatment over ordinary steel balls disappears when the various grades of balls are cold worked, or in other words, *there appears to be a limit to the hardness value obtainable by cold working hardened steel irrespective of composition and previous heat treatment.*"

This broad statement, if correct, is of considerable metallurgical interest, quite aside from its bearing on the Brinell ball problem. A double-barreled problem was thus presented:—first, can any special alloy be found which, upon work-hardening, will be more resistant to permanent deformation than plain carbon steel; second, if such a steel is found, will work-hardened balls

made of it show appreciable improvement in precision of Brinell testing hard steel?

The Engineering Mechanics section of the Bureau of Standards thought that although the present Hultgren balls serve well for precision hardness testing up to perhaps 650 Brinell, and even though the amount of testing that would be done on still harder steels is small, yet if a ball could be produced that would give still more nearly accurate results on the hardest steels it would be a desirable addition to testing equipment. To obtain an impression of sufficient size to allow fair accuracy in measurement, as well as to allow direct comparison with ordinary practice, it is not desirable to go below the 10-millimeter diameter of the standard ball. "Baby Brinell" tests on extremely hard steels cannot be expected to be as useful as Rockwell or similar diamond cone tests.

Beside the expense and difficulty of preparing 10-millimeter balls of diamond, ruby or sapphire, these materials cannot be expected to stand up well under the 3000-kilogram load in testing very hard steels. It was therefore thought worth while before turning to other materials to consider the possibilities in the development of a special steel ball less subject to flattening than those now available.

That there was some hope of accomplishing this, in spite of Hultgren's conclusion that the hardness of work-hardened carbon steel could not be exceeded, had been indicated by previous experience with an alloy of iron, carbon and vanadium which had been examined in the course of a study of etching reagents for alloy steels[12] and found to be both hard and forgeable. Preliminary tests[13] with heat treated cones of this material indicated that it should make a rather good Brinell ball. Hence, at the suggestion of the Engineering Mechanics section, which is seeking improvements in Brinell testing, and because of its own interest in the metallurgical problem involved, the metallurgical division undertook a further study of the material.

The experimental work consisted of two parts, first a brief study of ordinary and Hultgren balls to serve as a basis for comparison, second, the preparation and testing of heat treated and work-hardened iron-carbon-vanadium alloy balls.

[12]Groesbeck, E. C.—Metallographic Etching Reagents, III; For Alloy Steels. Bureau of Standards Scientific Paper No. 518, 1925.

[13]By Petrenko, S. N.—Engineering Mechanics Section.

II. Preliminary Comparison Tests

Considerable difficulty was experienced in measuring the diameter of the impressions made on hardened steel both with the commercial, work-hardened and etched Hultgren balls and with the ordinary ball. A comparator with which the diameter of impressions could be read to a hundreth of a millimeter with more accuracy than with a Brinell microscope, was used. Several diameters of the balls were measured on a bench micrometer to an accuracy of ∓ 0.00005 inch and all the balls that were measured and tested were found within this limit.

A series of hardness impressions were made on a hard piece of quenched gage steel. Seven impressions were made with a new Hultgren and seven with a new ordinary ball, the ball in each case being held in the same position in the Brinell holder for all seven impressions. The depth of impression was determined by measuring with a micrometer the thickness of the specimen of steel over a small ball lying in the impression. From this value, the thickness of the specimen, and the diameter of the small ball, the depth of the impression was calculated. The flattening was determined with a bench micrometer by measuring the diameter, over the flat spot and deducting the value from the original diameter of the ball. The results of these comparison tests are given in Table I.

Table I
Comparison Tests of Ordinary and Hultgren Brinell Balls

	Hultgren Ball			Ordinary Ball		
	Dimensions of ball in.	Brinell Number	Depth of Impression in.	Dimensions of ball in.	Brinell Number	Depth of Impression in.
Original diam.	0.3934			0.3936		
1st impression		700	0.0018		662	0.0011
2nd impression		700	0.0018		653	0.0011
3rd impression		700	0.0018		661	0.0011
4th impression		700	0.0018		653	0.0011
5th impression		700	0.0018		653	0.0011
6th impression		700	0.0018		653	0.0011
7th impression		700	0.0018		653	0.0011
		Av. 700			Av. 655	
Diam. ball over flat spot	0.3926			0.3914		
Ball Flattened	0.0008			0.0022		

It is seen from the above table that the diameters and hence the hardness numbers, (to which no correction for flattening has been applied), as well as the depth of the impressions were the same

for each impression made with the Hultgren ball and practically the same for each impression made with the ordinary ball. The depth of impressions in the latter case were also exactly the same. The ratio of the flattening of the ordinary balls to the Hultgren balls was 22 to 8, approximately 3 to 1. In this hardened steel specimen the Hultgren ball made an impression some 60 per cent deeper than did the ordinary ball.

From the diameter of the balls used in obtaining the data of Table I, and the diameter of the impressions made with each type of ball, it is possible to calculate what the depth of the impression would be if the impression were spherical. The calculated depths of impression for the two cases were 0.0054 inch for the Hultgren ball and 0.0058 inch for the ordinary ball. The measured depths were, 0.0018 and 0.0011 inch respectively, a difference between the calculated and measured depths of impression of 0.0036 inch for Hultgren ball and 0.0047 inch for the ordinary ball. The difference between the calculated and measured depth of the impressions is due in part to deformation of the balls, only 0.0008 inch of which is permanent set in the Hultgren ball, whereas 0.0022 inch is permanent set in the ordinary ball when used on this steel specimen. The balance of the difference must be due to elastic deformation of the ball and to the elastic recovery of the indented specimen.

Foss and Brumfield[14] computed the diameter of spheres fitting the impression made by a 10-millimeter ball under 3000-kilogram load for 30 seconds for tests made on steels of about 600 Brinell, which varied from about 23 millimeters with an ordinary ball down to 14 with a special Hultgren ball, taken as the hardest then available but probably not a work-hardened ball, this work being reported two years before Hultgren reported on his work-hardening tests.

III. Preparation of an Iron-Carbon-Vanadium Alloy

A small (1000-gram) ingot of an iron-carbon-vanadium alloy was prepared similar in composition to the alloy originally made for the etching reagent tests and from which the indenting cones had been made for preliminary tests. This alloy was made in

[14]See ref. 5—Their Table II and Fig. 13.

the high frequency induction furnace in a zirconium silicate crucible. The crucible charge of a low carbon welding rod steel was melted and additions made of carbon, as graphite, and vanadium, as 35 per cent ferrovanadium, to give a melt of approximately 3 per cent carbon and 12 per cent vanadium. The melt was poured at a temperature of approximately 3090 degrees Fahr. (1700 degrees Cent.). The analysis of this melt showed it to be of the following composition:

Carbon	2.93 per cent
Manganese	.10 per cent
Sulphur	.015 per cent
Silicon	1.55 per cent
Vanadium	13.5 per cent

The chill-cast ingot was forged hot to a bar about $\frac{5}{8}$ inch square from which 6 Brinell balls were prepared in the Bureau machine shop with the diameter about 0.001 inch over size.

IV. Heat Treatment of Iron-Carbon-Vanadium Balls

Specimens of these slightly over-size iron-carbon-vanadium alloy balls were given heat treatments designated A, B, and C, respectively, as shown in Table II. Treatment C might be termed a high speed steel treatment.

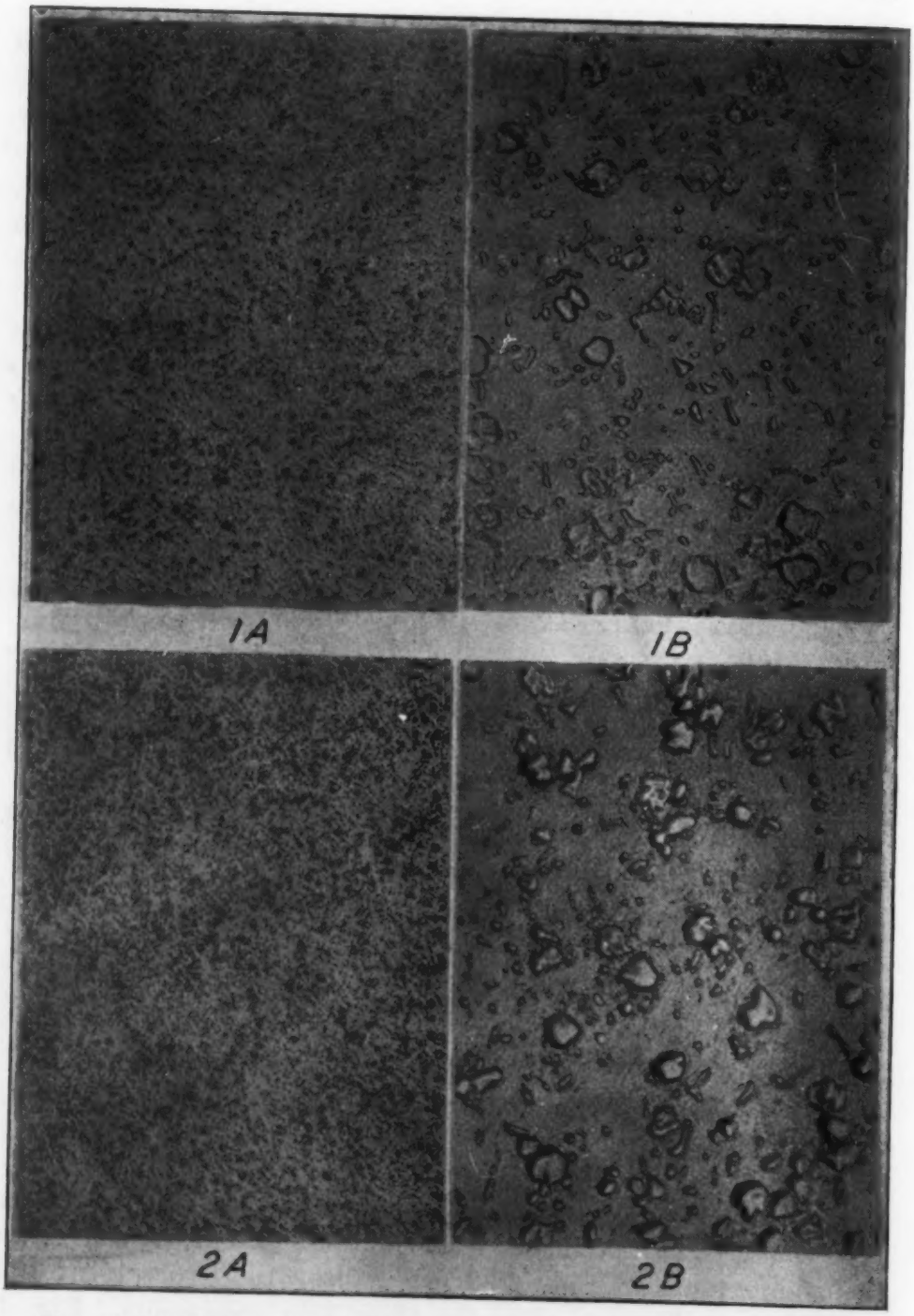
Two balls were subjected to each of the three treatments and ground to the finished size of a 10-millimeter (0.3937 inch) Brinell ball.

Sections from specimens of the iron-carbon-vanadium alloy of each of the three heat treatments were examined under the

Table II
Heat Treatment of Iron-Carbon-Vanadium Alloy Balls

Treatment	Quenching Temperature°C	Quenching Medium	Tempering Temperature°C
A	850—30 min.	water	100—30 min.
B	925—30 min.	oil	100—30 min.
C	870—30 min. 1260— 2 min.	oil	100—30 min.

microscope. The specimens were polished but unetched. The photomicrographs in Figs. 1, 2 and 3 show the structure at 100 and 500 magnifications after the three heat treatments. Fig. 1 shows that for heat treatment "A" the carbide particles are uniformly distributed throughout. In Fig. 2 the same uniform distribution is noted for heat treatment "B"; whereas, Fig. 3 shows



Figs. 1A and 1B—The Above is Representative of the Structure Found in Iron-Carbon-Vanadium Alloy of Heat Treatment A. The Carbide Particles were Very Uniformly Distributed Throughout the Matrix. Unetched. Figs. 2A and 2B—Structure of Iron-Carbon-Vanadium Alloy of Heat Treatment B. Here Again the Structure was Very Uniform. The Structure is Essentially the Same as That Shown in Figs. 1A and 1B. Unetched. Figs. 1A and 2A—Magnification 100 x. Figs. 1B and 2B—Magnification 500 x.

that for heat treatment "C" the carbide particles are not uniformly distributed but that small patches, at 100 diameters magnification, are shown distributed throughout. Fig. 3 also shows views of the material and of one of the patches at 500 diameters.

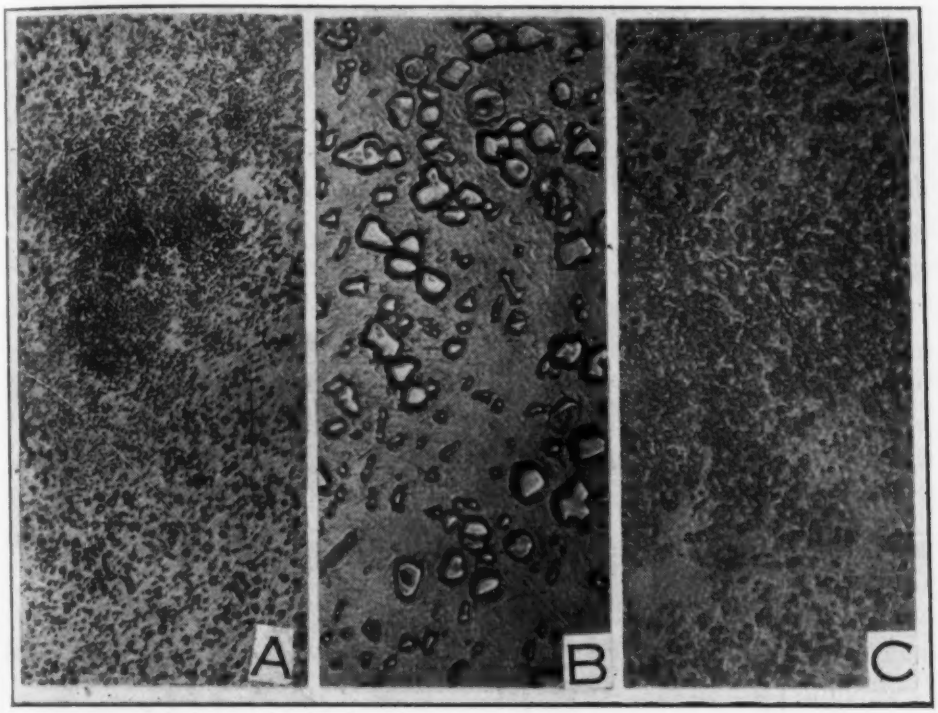


Fig. 3.—Iron-Carbon-Vanadium Alloy of Heat Treatment C: Micrograph A showing the non-uniform distribution of the carbide particles in Iron-Carbon-Vanadium Alloy of Heat Treatment C; Micrograph B showing at higher magnification an unsegregated portion of micrograph A; Micrograph C showing at higher magnification a segregated portion of A. Unetched. Fig. 3 A, magnification 100 X; Figs. 3 B and 3 C, magnification 500 X.

The ball of heat treatment "C" later broke when cold work was undertaken at a smaller load than was endured by the balls of the other heat treatments. This indicated that the segregated areas probably resulting from this heat treatment rendered the material unfit for subsequent work hardening.

V. Tests on Heat Treated, Iron-Carbon-Vanadium Balls

Brinell tests were made with one ball of each of these heat treatments under the standard load of 3000 kilograms against four standard steel bars of hardness about 420, 560, 690, and 710 respectively. The standards were designated by the numbers 4, 3, 2 and 1, increasing in hardness in the order in which the numbers are given.

Table III

Tests with iron-carbon-vanadium alloy balls of various treatment, The Hultgren ball and the ordinary ball against four steel "standards".

Tests	Data	TYPE OF BALL: Fe-C-V Ball Heat Treatment "A" cold worked under following loads per ball — Zero	1450 kg	1950 kg	Fe-C-V Ball Heat Treatment "B" cold worked under following loads per ball — Zero	1450 kg[1]	Fe-C-V Ball Heat Treatment "C" — Zero[1, 2]	Hultgren Ball cold-worked under 2200 kg per ball. Etched Balls	Ordinary Ball Heat-treated but not cold-worked
Flattening Tests Against Steel "Standard" No. 4	Flattening of Ball, in.[3]	.0001	.0000	.0000	.0001	.0000	.0001	.0000	.0001
	Depth Impression, in.[3]	.0060	.0063	.0066	.0059	.0061	.0058	.0060	.0060
	Brinell Number[3]	418	415	415	421	415	424	424	415
Flattening Tests Against Steel "Standard" No. 3	Flattening of Ball, in.	.0002	.0000	.0000	.0002	.0000	.0004	.0001	.0007
	Depth Impression, in.	.0042	.0042	.0042	.0040	.0042	.0040	.0040	.0038
	Brinell Number	555	555	555	555	555	562	562	543
Flattening Tests Against Steel "Standard" No. 2	Flattening of Ball, in.	.0007	.0002	.0003	.0006	.0003	.0010	.0004	.0017
	Depth Impression, in.	.0022	.0022	.0022	.0022	.0023	.0019	.0021	.0017
	Brinell Number	676	700	700	688	700	682	682	653
Flattening Tests Against Steel "Standard" No. 1	Flattening of Ball, in.	.0011	.0004	.0003	.0010	.0004	.0014	.0008	.0022
	Depth Impression, in.	.0015	.0017	.0018	.0016	.0019	.0015	.0017	.0013
	Brinell Number	706	712	712	700	712	704	704	688
Rebound	Per cent Rebound	85	85.6	85.7	85	85.5	82	86.5	83
Rockwell diamond cone test on ball	Rockwell "C" number	..	65	..	..	..	..	64.5	..

[1]Balls broke of treatment "B" and "C" during attempt to cold work at 1950 kg.
[2]Did not attempt to cold work ball of treatment C at 1950 kg.
[3]The results in this table for flattening of the ball's, depth of impressions and Brinell number are the average of several closely agreeing observations.

Each ball was tested against the softest of these standards first and then against the others in the order of their increasing hardness. The flattening of the balls was determined after each test. The ball was replaced in the holder of the Brinell machine with the same spot down for each succeeding test but, of course, fresh places on the specimens were used for each succeeding test. The flattening of the balls was measured with a micrometer in the same way as in the comparison of Hultgren and ordinary balls. The Brinell numbers were taken from the diameter of the impressions on each of the steel standards. The depths of the impressions were measured directly with a micrometer over a steel ball lying in the depression. Table III includes the results of tests on the iron-carbon-vanadium balls of each heat treatment, the ordinary ball and the Hultgren ball. It includes also tests on the work-hardened specimens described in the next section. No correction for flattening has been applied to any of the Brinell numbers given in Table III, they are simply derived from the measured diameters of the impressions by use of the usual Brinell tables.

Rebound tests were also made on all these balls. In these tests balls were dropped from a height of 2 meters on a hardened high speed steel die block and the height of rebound was measured as an indication of the elastic recovery. The ball was held in the mouth of a tube suspended from above and connected to the vacuum system. When the suction was released, the ball dropped and rebounded from the steel die. About twenty readings were taken on each of the iron-carbon-vanadium balls of the three heat treatments while more were made with the ordinary and Hultgren balls since more balls of these types were available. The results were averaged and the per cent rebound computed for each kind of material. Table III includes the results of the rebound tests.

In Fig. 4, curves are plotted for each of the five types of balls as well as for the work-hardened alloy balls discussed later; the flattening of the balls after supporting the 3000-kilogram load for 30 seconds on the various steel "standards" is plotted against the Brinell numbers (determined with Hultgren ball).

The Hultgren ball flattened the least, the iron-carbon-vanadium balls next, and the ordinary ball the greatest amount when tested

against these hardened steels; one of the iron-carbon-vanadium balls, the one having had the high speed steel heat treatment "C", flattened more than the other two which were resistant to permanent flattening to nearly the same degree as the Hultgren ball.

The results of the rebound test fall fairly well in line with the results of the flattening tests except that the iron-carbon-

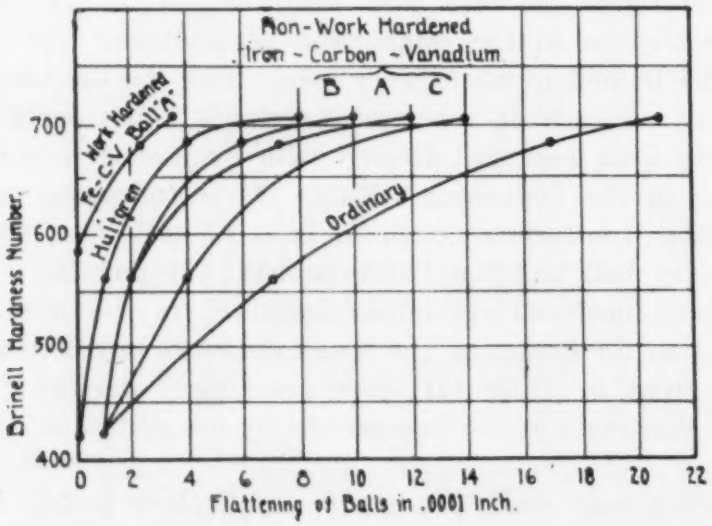


Fig. 4—The Flattening of the Five Types of Balls After Supporting 300 Kilogram Load for 30 Seconds on Four Steel "Standards" is Plotted Against the Brinell Number (Determined with Hultgren Ball).

vanadium alloy ball of treatment "C" gave values lower than the ordinary ball, whereas in the flattening test, the ordinary ball suffered the greater permanent deformation.

VI. Work-Hardening the Iron-Carbon-Vanadium Balls

The ball race selected for use in work hardening these balls was one originally containing 11, $\frac{13}{32}$-inch balls. This was a medium duty bearing, but was the only type available which carried the nearest size ball next above the standard 10-millimeter (0.3937-inch) ball. A special spacer, to hold 9 balls, was constructed with openings on one side to permit a brush to rub and turn the balls slightly each time they passed the point of no load in the race. The two parts of this special spacer were held together with screws which permitted the removal and replacement of the balls at will. The inner race was fitted on a spindle which in turn was mounted in the chuck of a heavy lathe. The outer race was contained in a steel collar which added stiffness to this member. This collar

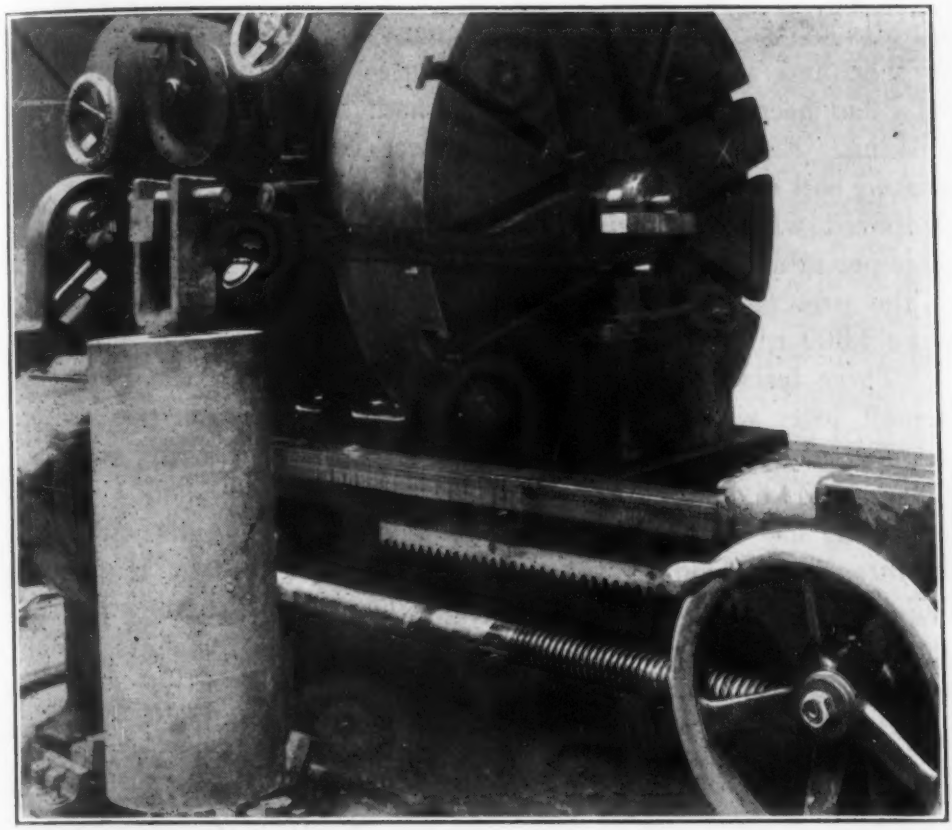


Fig. 5—Photograph of Apparatus for Work Hardening Balls. The Weight on the End of the Lever Applies a Force Upward Against the Bearing which is Immersed in a Tray of Mineral Oil.

was machined flat at one point on its periphery against which point a force was applied upward through a lever which was mounted on the frame of the lathe and carried a weight of 340 pounds (154 kilograms) from the other end. With a lever ratio of 17 to 1, this weight caused the opposite end of the beam to exert an upward force against the bearing of 5780 pounds (2620 kilograms). According to the Stribeck formula this corresponds to a maximum load on each ball of about 1450 kilograms or about half the load imposed in the Brinell test. A tray of mineral oil which was deep enough to submerge the bottom balls was placed under the races and kept the balls continuously lubricated. Fig. 5 is a photograph showing the equipment in position for service.

A preliminary trial was made to see how well ordinary Brinell balls would harden with this equipment. The race was filled with ordinary Brinell balls and run for 200 minutes at a speed of 26 revolutions per minute. A ball was removed at the end of 100

minutes of running and at subsequent intervals of 20 minutes, another and soon until at 200 minutes of actual running, six balls had been removed each having had different degrees of cold working. Each ball when removed was replaced by another unworked ball to keep the race full. This speed was relatively slow compared with the speed Hultgren used, namely, 2,000 revolutions per minute for 2 minutes or 4,000 revolutions in all; whereas, in the present test approximately 160 minutes were required to make 4,000 revolutions.

These tests showed that the work hardening of the ordinary Brinell balls with this equipment gave them greater resistance to permanent deformation; since thereby their flattening was reduced from about 0.0022 inch to as low as 0.0009 inch, a value nearly as low as with the commercial Hultgren balls although the intensity of loading was only about ⅔ that used by Hultgren. The values for flattening were not always consistent with the time of test, but no effort was made toward refinements which would tend to minimize these variations.

Of the three pairs of iron-carbon-vanadium alloy balls, one of each of the three heat treatments had been tested after heat treatment alone. The other ball of each of the heat treatments A, B, and C, was then used for work hardening experiments. These three balls were placed in spaces in the spacer marked A, B, and C, which corresponded to the letters designating the heat treatments, that the balls had received. The remaining six spaces were filled with Hultgren balls. For work hardening, the same load was applied against the bearings through the lever as in the preliminary trial. At the end of about 50 minutes the ball of heat treatment "C" broke in half without, however, damaging the race or spacer since the lathe was stopped at once; the broken ball was removed and replaced by a Hultgren ball. The work hardening was continued without further mishap until a total of two hundred minutes had elapsed, when the treatment was stopped.

The two iron-carbon-vanadium alloy balls had developed some slight colorations or small markings on the surface.

Since the load per ball used in work hardening was only about 1450 kilograms and the load used in Brinell tests of steel is 3000 kilograms, it was suggested that an experiment be tried

with a total load of 3500 kilograms or 2200 kilograms per ball for 8 balls, which Hultgren found could be used without causing premature failure of the balls and races. Sufficient additional load was hung from the end of the beam to give a total pressure against the ball bearing of 3500 kilograms or about 1950 kilograms per ball for 9 balls, and the experiment was started with two iron-carbon-vanadium balls of heat treatments "A" and "B" respectively, in the race with the other seven spaces filled with Hultgren balls. This load proved to be about the limit at which the balls could be worked for even at this load the inner race split on the first trial. When the broken race was replaced and the test continued, iron-carbon-vanadium ball of heat treatment "B" broke in pieces. The space was filled with another Hultgren ball and the test continued on the "A" ball for a total of 200 minutes without further mishap.

The results of test on the same hardened steel standards with iron-carbon-vanadium ball of heat treatment "A" worked under a load of 1950 kilograms compared with results obtained when worked at 1450 kilograms and when heat treated but not cold-worked are given in Table III.

It is shown by these results that cold working at a load of 1950 kilograms increased the resistance of the balls to permanent deformation only a slight amount over what it was for a load of 1450 kilograms. Also this test shows that a 1950-kilogram load per ball is great enough to cause considerable trouble from failure of the races used.

Further increase of loading up to the 2200-kilogram maximum load per ball used by Hultgren was not attempted because no heavy duty races were available.

VII. Tests on Work-Hardened Iron-Carbon-Vanadium Balls

Rebound, flattening, and Brinell tests were made as before, and the results, together with those on balls which had been heat treated but not cold-worked, are given in Table III.

The work-hardened balls averaged slightly superior in elastic recovery in the rebound test than before work hardening, but the values were in both cases more scattering than the results obtained with the Hultgren ball or the ordinary ball.

It should be noted that the sphericity and smoothness of the

alloy balls, made in a shop not specially equipped for making balls, were not as good as in the case of the ordinary commercial balls made with special equipment. Since lack of perfect sphericity and smoothness will affect the rebound tests. The apparent indication of the rebound tests to the effect that the Hultgren ball was harder than the work-hardened alloy ball cannot be taken as conclusive.

Rockwell diamond cone tests made on a Hultgren and a work-hardened alloy ball by the Engineering Mechanics section, also given in Table III, show only slight difference, but in this case the indication is that the alloy ball is the harder.

But if "resistance to permanent deformation" is taken as the criterion of hardness, then the flattening tests given in Table III, should serve to define the hardness of the balls. On this basis, the decidedly smaller flattening of the worked alloy balls, as compared with the worked carbon steel balls fails to confirm Hultgren's conclusion, that no heat treated and cold-worked alloy steel can be made superior in hardness to a heat treated and cold-worked plain carbon steel.

The flattening of a heat treated but unworked ordinary carbon steel ball in making a Brinell test on specimen 1, of 710 Brinell, was 0.0022 inch, that of the Hultgren cold-worked carbon steel ball was 0.0008 inch. These flattening figures are exactly the same as were obtained on a 700 Brinell steel and given in Table I. The flattening of the ordinary ball after cold working in the Bureau's apparatus was 0.0009 inch.

On the 710 Brinell steel, the flattening of the unworked alloy balls with the heat treatments A, and B, was 0.0010-0.0011 inch, and on cold working it fell to 0.0003-0.0004 inch.

The alloy steel was much harder in resistance to flattening than the carbon steel in the simple heat treated condition, and it has gained that type of hardness upon cold working, the original superiority not disappearing as Hultgren says it will "irrespective of composition and previous heat treatment."

VIII. The Work-Hardened Alloy as a Brinell Ball

Examination of the corresponding Brinell numbers obtained in the tests of different steels, however, does not show significantly higher values from the work-hardened alloy balls.

Brinell measurements on hard steels are always subject to considerable variation. In a series of repetitions on the same steel, Hultgren's individual values varied from 703 to 723, (average 711). A variation of ± 10 points appears to be about the limit of accuracy of reading on these hard steels. This range is greater than the extreme differences found in the averages from the Hultgren and the work-hardened alloy balls.

The Bureau results for the steel which averaged 690 Brinell number were 682 for the Hultgren ball, 700 for the work-hardened alloy balls. A few readings were taken by the Engineering Mechanics section on one work-hardened alloy ball (Treatment A, 1450-kilogram per ball) for the purpose of judging the quality of the impressions. They reported that the impressions made by the alloy ball appeared to be a little better defined, though the difference was not marked. These tests gave, on a particular specimen of hard steel, a Brinell number of 650 with the Hultgren and one of 695 with the alloy ball. Differences as large as this did not appear in the longer series of tests, which were, however, made on different steel specimens.

By an extrapolation which Hultgren states gives "somewhat arbitrary" corrections, he concludes that figures obtained with the work hardened Hultgren ball require a correction of +9 to a figure of 686 and +24 to one of 711, to compensate for flattening.

Since in the Bureau test a Hultgren ball which flattened 0.0008 inch gave a Brinell number of 704, and the alloy balls which flattened 0.0004 inch gave a Brinell number of 712 it would appear that Hultgren's correction is too large. Since halving the permanent flattening of the ball does not raise the apparent Brinell number enough to overbalance observational errors at 700 Brinell, it would appear that, up to that hardness the results obtained with the commercial Hultgren ball will not be increased in accuracy by the use of a correction for permanent flattening obtained by extrapolation.

On steel of around 700 Brinell, the permanent flattening of the Hultgren ball does not appear sufficient to lower the apparent hardness number materially so that this work indicates that the commercial Hultgren ball gives more trustworthy results upon very hard steels than was claimed by Hultgren.

The need for special Brinell balls has, of course, been decreased by the introduction of the Rockwell hardness tester, which uses a small, relatively inexpensive diamond cone for testing the harder steels. Tests by the Brinell method are, however, often required on very hard steels, either to corroborate Rockwell tests in research work, or where no Rockwell instrument is available. The greater part of such Brinell testing can be done with sufficient precision with the commercial Hultgren ball. In the few cases where greater precision is needed, in testing the very hardest steels, balls of the 3 per cent carbon, 13 per cent vanadium alloy, quenched into water from 1560 degrees Fahr. (850 degrees Cent.), tempered at 212 degrees Fahr. (100 degrees Cent.), brought to size and work-hardened by the Hultgren procedure under about 2000 kilograms maximum pressure per ball should be preferable on theoretical grounds, since the permanent flattening of the ball is halved. One would expect that on a steel of, say, 800 Brinell, were such available for testing, the precision might be considerably better than with work-hardened Hultgren balls.

Inasmuch as the need for alloy balls would thus be limited, to the testing of steels of almost unattainable hardness, the Bureau has not proceeded further with the production of such balls, but puts the experiments on record so that those who may have need for them may prepare them.

IX. Influence of Modulus of Elasticity on Brinell Impressions

This investigation has indicated clearly that the permanent deformation of the ball is not the only factor affecting the impressions on very hard materials. As was noted on page 8 the permanent deformation accounts for only a small part of the deviation of the curvature of the impression from that of the undeformed ball. The rest must be ascribed to elastic deformation of ball and steel, which will depend for its value on the elastic properties of the ball.

Hertz's[15] original work and Auerbach's[16] long series of investigations on hardness, point this out clearly. In Auerbach's work the difficulty was overcome by making the indenting ball

[15]Hertz, H. Vern. Verl. Physik Ges. 1, p. 67, 1882; Crelle's Journal, 92, p. 156, 1882.

[16]Auerbach, F. Wied. Ann. 58, p. 381, 1896.

of the same material as the indented surface. Since the introduction of the steel ball by Brinell this influence seems to have received little consideration.

No obstruse calculations are required to bring out the fact that elastic deformation must be a factor. If a Brinell test of wax were made using an ivory ball and a soft rubber ball, the impression made with the rubber ball would have a much larger diameter because it would deform more, though neither ball would have any permanent deformation after the load was released. Permanent flattening of the ball would have a similar effect in making a larger impression. But when the point is reached, as it seems to be with the Hultgren ball on a 700 Brinell steel, where permanent flattening has been lowered to such a degree that further lowering has no appreciable effect, the so far uncalculated effect of elastic deformation may play a large part in the difficulty of making precision Brinell tests on very hard steel.

Obviously the elastic distortion will be less if the resistance of the ball to deformation is increased by the use of sapphire, ruby, corundum or diamond balls instead of steel. Lack of agreement between tests with diamond and steel balls cannot be laid wholly to the permanent flattening of the steel ball.

Devries[17] comments on this and concludes that "the calculation of the hardness numeral as advised by Brinell retains no significance unless we replace D in the formula $\frac{P}{\pi t D}$ by the diameter of the sphere of which the indentation forms the segment."

The evaluation of the effect is even then not simple. Sapphire, ruby, corundum and diamond are crystalline but not isotropic so that theoretically the shape and depth of the impression will change for each orientation of the ball. It is perhaps possible that some of the discrepancies observed with diamond cones are due to this fact. From the elastic constants of corundum found by Auerbach[18] it seems probable that corundum would give much less elastic deformation than steel. For diamond only the cubic compressibility has been measured by Adams[19], giving 81,000,000 pounds

[17]Devries, R. P. Comparison of Five Methods Used to Measure Hardness. Bureau of Standards Technological Paper No. 11, 1912, p. 12.

[18]Auerbach, F. Wied. Ann. 43, pp. 61-100, 1891.

[19]Adams, L. H. Jour. Wash. Acad. Sci. 11, pp. 45-50, 1921, and Adams, L. H. and Williamson, F. D. Jour. Frank. Inst. 195, pp. 492-3, 1923.

per square inch for the compressive modulus so that only a guess can be made as to its behavior, but since this is much higher than any other known compressive modulus (corundum being only 38,000,000 pounds per square inch) it is probable that diamond would deform even less, but this cannot be definitely stated, without a knowledge of its other elastic properties. Observations indicate, however, that it is much less deformable than steel. This subject deserves further study.

X. Conclusions

1. Work-hardened iron-carbon-vanadium steel balls have been produced more resistant to permanent deformation than Hultgren balls.

2. For testing materials up to 700 Brinell these offer no appreciable advantage over Hultgren balls.

3. For testing materials of 800 Brinell or over these new balls should presumably be superior to the Hultgren ball.

4. In tests of these harder materials the elastic deformation of the ball plays a major part so that for still harder materials there is needed not only a greater resistance of the ball to permanent deformation but also greater resistance to elastic deformation.

XI. Acknowledgements

Grateful acknowledgement is made for the assistance rendered by Dr. H. W. Gillett, Chief of the Division of Metallurgy, through his constructive criticisms during the laboratory tests and the preparation of this report; also for the co-operation of the Engineering Mechanics section, especially that of L. B. Tuckerman, Senior Engineer-Physicist. Useful suggestions have also been given by H. S. Rawdon, Senior Metallurgist.

DISCUSSION

A. H. d'Arcambal: Mr. Quick is to be congratulated for this very excellent paper, the best of its type I have ever seen in print. I cannot see, however, why one continues to use the Brinell machine on hard materials when the Rockwell instrument has proved so efficient.

Recently we took a piece of carbon tool steel, hardened it and tempered it to 350 degrees Fahr. We took another piece of high speed steel, quenched it from 2350 degrees Fahr. and tempered it to 1100 degrees Fahr. We then made Rockwell tests and Brinell tests on these specimens, then submitted the same to the hot acid etch test. It was interesting to note that the Brinell

machine produced strains that opened into large cracks in both materials, whereas no cracks developed around the impressions made by the Rockwell machine.

I believe that in the next few years the Brinell machine will be used only on the softer materials, the Rockwell instrument being the standard for harder materials, unless a better machine is developed by that time.

E. C. BAIN: With the growing field of Rockwell testing rendering it less necessary for Brinell testing, I suppose the development of a better material may perhaps lose value commercially, but I think there is still ample reason for improvement in Brinell balls. It occurred to me that perhaps this new alloy might possibly suffice to make a cheaper cone for the Rockwell machine, to be used up to a certain hardness, to avoid the possible breakage of diamonds. I wonder if Mr. Quick would tell us about some of these features?

G. W. QUICK: We realize that the Rockwell machine has largely filled the needs in the field of testing of hard materials. For special experimental work and probably some commercial testing we feel that there is still a field for the Brinell test, particularly in some cases where a Brinell machine is available, whereas the Rockwell machine may not be.

E. L. ROFF: I would like to ask this question, whether the accuracy of the results obtained from the Rockwell machine are any greater or less than that obtained with the Brinell machine when taking into account the error due to the flattening of balls. I do not mean to criticize the Rockwell tester. We use them, and we think well of them, but on the other hand I have often wondered whether one point in the Rockwell does not cover more territory than a difference in the Brinell readings that we might get through this error.

DR. H. W. GILLETT: Mr. Chairman, even though the Rockwell test will meet most of the industrial needs in these hard steels, for experimental purposes, there are many times when one wants to compare hardness and be sure of small differences, and it is highly desirable to be able to use two or three different kinds of tests; therefore, even though the Brinell test might pass out entirely for testing hard steels for commercial uses, there would be many times in experimental work when one would want to corroborate and check up just exactly the point the previous speaker was making, whether a half point on the Rockwell means something or whether that deviation is within the errors of observation.

In attempting to determine the hardness of these balls themselves, there was only a very slight difference in the Rockwell figures, and an equally slight difference in the rebound test. Without the results of the flattening tests, which do show material work-hardening, there would be no conclusive evidence as to which ball was the harder. Reliance upon one single method of hardness testing would be unsatisfactory for much research work.

There has been some discussion among us at the Bureau as to whether we were sufficiently precise in our phraseology in regard to Hultgren's statement that steel, no matter what its composition or heat treatment, reaches a definite maximum of hardness on work hardening, that is that the carbon steel could not be surpassed. The question is whether this alloy is steel or not. An alloy of 2.93 per cent carbon and 13.5 per cent vanadium and 1.5 per cent silicon

certainly is not cast iron. I do not think anybody will claim that. If we take the ordinary definition of steel, say up to 1.7 per cent carbon, it is not a steel.

Merten has paved the way very nicely in the paper read just before this one by having an alloy of 2.35 per cent carbon and 12-13 per cent chromium, and he has no hesitation about calling that a steel, and inasmuch as this vanadium alloy also certainly has properties more nearly like those of steel than of cast iron, we have felt that it probably fell into the steel class, although in the title of the paper we called it an alloy.

E. C. BAIN: That steel containing well over 2 per cent carbon and 10 per cent or more chromium forges so well and is so typically steel in behavior that I would be inclined to think that we will always regard it as steel.

DR. R. W. WOODWARD: Mr. Chairman, the authors of this paper are to be congratulated on their efforts in introducing a super-hard steel.

There is one point that I would like to ask about. That is in the photomicrographs which were shown of heat treatment "C", as I recall it they showed segregation, and the question naturally arises whether that segregation was due to the heat treatment or whether it was segregation which was originally present in the material. I would like to inquire whether photomicrographs were taken on similar pieces of other steels to check that point?

Another phase of the problem, in his review of previous papers Mr. Quick mentioned work by R. C. Brumfield on Rockwell hardness tests, which indicated that the Rockwell cone tests produced distortion. I think those results have been somewhat questioned; in fact, I have personally taken Rockwell cone impressions on the hardest materials which I could obtain, and made cross sections through those impressions. A magnification of 500 diameters failed to show any difference between the impression and the angles in the original cone.

DR. H. W. GILLETT: That would only hold up to a certain hardness of steel. There must be a deformation.

DR. R. W. WOODWARD: That was the hardest material I could obtain. I suppose that it is true; if used on these materials you would find some deformation, but in commercially hard materials there is no deformation.

G. W. QUICK: Mr. Chairman, I might say in reply to Dr. Woodward's question about photomicrographs that we did not take photomicrographs of other samples of the alloy of heat treatment "C." We had a limited amount of material available and did not make any duplicate heats.

E. C. BAIN: Mr. Quick, will you please tell us whether or not this steel was soft as annealed and how it behaved in heat treatment with various quenches and tempers. For example, it seemed to me that the photomicrograph which you showed did not appear martensitic. While we can recognize the particles, yet I am wondering what the matrix really consists of.

G. W. QUICK: We did not go into just what the matrix is, but I do not believe it is martensite. It is possibly vanadium dissolved in iron.

E. C. BAIN: It occurs to me also that it is perhaps merely a case of a considerable difference in hardness between the hot condition and the cold condition. That is to say, it is forgeable and malleable while hot, but at lower

(Continued on Page 50)

EFFECT OF HEAT TREATMENT ON THE COMBINED CARBON IN GRAY CAST IRON

By E. L. Roth

Abstract

The author gives the results of a series of experiments carried out to determine the effect of heat treatment on the combined carbon in gray cast iron. Heat treating is necessary when sufficient carbon has combined to form hard spots of cementite.

Samples of two gray irons of different carbon and silicon content were used. These samples were heated to various temperatures. The maximum of graphitic carbon was precipitated at 1400 degrees Fahr. in both cases.

Microscopic examination shows that the formation of graphitic carbon is propagated from the edges toward the center.

Because of the closeness of the results obtained even though the different samples had a wide variation in silicon content, it is believed that the silicon does not have a marked effect on graphitizaton. It is also shown that the degree of graphitization does not increase with a rising temperature.

THE term "heat treating" is not usually associated with gray cast iron. The application of heat to gray cast iron, however, produces structural changes with an accompanying change in physical properties. In practice, many gray iron castings are annealed, that is, reheated for a certain length of time, the reason being twofold:

1. To relieve internal strains set up by primary crystallization produced during the solidification of the iron.
2. To soften the castings by eliminating the surplus combined carbon, which appears as hard spots and white edges, making impossible a normal working in the machine shop.

The ideal casting is one which has a close grain in all sections, and is readily machinable in all sections. However, in order to obtain this condition in plain gray iron, the silicon content must be held within close limits. It is when the silicon content goes to the low side, due to cupola conditions et cetera, causing hard spots

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to appear in the castings, that heat treatment must be resorted to.

The assumption is made that, in such cases, the maximum transformation of Fe_3C into graphitic carbon and iron produces the softest and most easily worked cast iron, because this means the segregated areas of the hard unmachinable cementite have been eliminated. The annealing always leads to a weakening of the iron. Gray cast iron consists of a matrix of ferrite or silico-ferrite, strengthened by pearlite, which is interspersed and weakened by numerous graphite plates, not to mention the phosphide constituent usually present. If the silicon content is lower than the dimensions of the section require, cementite membranes will also be found which strengthen the material, particularly when under compression.

When the microstructure of a piece of gray cast iron is examined, it is seen to consist of a matrix of ferrite with some pearlite and imbedded with graphite plates of a distinctly wormlike appearance. Pearlite has a strengthening influence in cast iron similar to that which it has in steel, and cast iron may be considered as being similar to steel, except that the graphite greatly weakens the structure, just as a similar number of cracks or cuts would weaken it. The breaking down of this pearlite structure is accompanied by a decrease in strength.

Cast Irons Used

Gray cast iron, because of the number of constituents and the conditions under which it is produced, has a wide range of composition. The properties exhibited by one cast iron would not necessarily hold for a cast iron of different composition. Since silicon is the most important constituent of cast iron after carbon, two cast irons of a high and a low silicon content were used in this investigation.

The analyses of the two cast iron which were numbered 1 and 2, respectively, are as follows:

Cast Iron No. 1	Per Cent	Cast Iron No. 2	Per Cent
Total Carbon	3.52	Total Carbon	3.25
Combined Carbon	0.50	Combined Carbon	0.43
Silicon	1.75	Silicon	2.70
Sulphur	0.05	Sulphur	0.068
Manganese	0.75	Manganese	0.92
Phosphorus	0.40	Phosphorus	0.22

Cast iron No. 1 was available as pot castings, 4 inches in

Table I

Carbon Content of Specimens of Cast Iron No. 1 when Heated at Various Temperatures

Temperature deg. Fahr.		CAST IRON NO. 1 Time in Hours ½	1	1½	2	2½	3
1200	Combined C	0.44	0.32	0.27	0.22	0.14	0.15
	Graphitic C						
	Total C	3.50	3.52	3.52	3.52	3.49	3.49
1300	Combined C	0.24	0.14	0.08	0.08	0.07	0.10
	Graphitic C						
	Total C	3.52	3.52	3.52	3.48	3.52	3.48
1400	Combined C	0.09	0.06	0.06	0.06	0.07	0.06
	Graphitic C	3.59	3.71	3.66	3.63	3.63	3.67
	Total C	3.67	3.77	3.71	3.70	3.69	3.72
		3.67	3.77	3.72	3.69	3.71	
1500	Combined C	0.18	0.12	0.11	0.11	0.10	0.13
	Graphitic C	3.52	3.56	3.60	3.60	3.66	3.60
	Total C	3.71	3.70	3.72	3.71	3.76	3.72
		3.73	3.70	3.71	3.69	3.75	3.70
1600	Combined C	0.22	0.21	0.20	0.20	0.21	0.21
		0.23	0.21	0.20	0.22	0.21	0.20
	Graphitic C	3.29	3.30	3.32	3.34		
	Total C	3.52	3.51	3.53	3.54	3.54	3.56
							3.58
1700	Combined C	0.23	0.24	0.23	0.22	0.22	0.23
		0.24	0.25	0.23	0.22	0.22	0.22
	Graphitic C	3.30	3.31	3.32	3.32	3.31	3.27
	Total C	3.55	3.55	3.56	3.54	3.54	3.50

diameter, and 5/16 inches in thickness. Cast iron No. 2 was available as automobile piston castings, 4 inches in diameter and 9/32 inch thick.

Procedure

Samples of the two cast irons were taken before they were heat treated and drillings were taken from all of the castings selected in order to get a representative sample. The samples were quartered until about 15 grams of each remained. The combined carbon was determined by the colorimetric method and the total carbon by the combustion method. The analyses are shown in Tables I and II.

The castings were sawed into semicircular segments about 1¼ inches in width. The heat treating furnace which was used in this experiment was heated to 1200 degrees Fahr. before the samples were placed into it, and care was taken to have a neutral atmosphere in the furnace. Six pieces of each of the cast irons were placed in the furnace and one of each was removed every half hour and cooled in air. This procedure was repeated for 1300, 1400, 1500, 1600 and 1700 degrees, Fahr.

Table II

Carbon Content of Specimens of Cast Iron No. 2 when Heated at Various Temperatures

Temperature degrees Fahr.		CAST IRON NO. 2 Time in Hours ½	1	1½	2	2½	3
1200	Combined C	0.39	0.36	0.31	0.22	0.17	0.18
	Graphitic C						
	Total C	3.25	3.25	3.25	3.22	3.28	3.28
1300	Combined C	0.18	0.14	0.13	0.12	0.12	0.12
	Graphitic C						
	Total C	3.30	3.28	3.29	3.28	3.28	3.26
1400	Combined C	0.12	0.11	0.10	0.09	0.10	0.11
	Graphitic C			3.24	3.25		
	Total C	3.32	3.33	3.34	3.34	3.31	3.28
		3.31	3.33	3.33	3.32	3.31	3.29
1500	Combined C	0.20	0.14	0.11	0.10	0.09	0.14
		0.21	0.14	0.10	0.10	0.09	0.13
	Graphitic C	3.09	3.19	3.20	3.24	3.23	3.18
	Total C	3.30	3.32	3.34	3.34	3.34	3.32
1600	Combined C	0.26	0.24	0.24	0.23	0.22	0.24
		0.25	0.24	0.24	0.22	0.22	0.24
	Graphitic C	3.06	3.05	3.04	3.06	3.05	3.02
	Total C	3.31	3.30	3.28	3.29	3.28	3.29
		3.31	3.29	3.28			
1700	Combined C	0.27	0.26	0.27	0.26	0.26	0.25
		0.28	0.27	0.26	0.26	0.27	0.25
	Graphitic C	3.00	2.98	2.99	2.99	2.98	3.02
	Total C	3.27	3.26	3.24	3.26	3.25	3.28

Drillings were taken from each heat treated piece, care being taken here also to keep out scale by discarding the first drill chips. The pieces were drilled to such an extent that practically one quarter of the piece was contained in the sample to be analyzed.

Analyses of the total carbon for each heat treated piece were made in order to detect any changes in the total carbon, and to furnish a means of checking the values of the combined carbon obtained by the colorimetric method.

By referring to the data for cast iron No. 1 in Table I it will be noticed that when the samples which were heated to 1400 and 1500 degrees Fahr. were analyzed, they showed a marked increase of total carbon. Although a standard had been run before making any analyses, at this point two analyses were made of each sample and a standard was run before each pair of samples. The figures obtained ,about 3.70 per cent carbon, showed that the heat treatment had not been responsible for this change, and the increase was attributed to segregation of carbon in several of the castings.

From the analyses, a gradual decrease in the combined carbon

was observed, reaching a minimum at 1400 degrees Fahr. At 1500 degrees Fahr. a larger amount of combined carbon remained in the iron and increasing amounts were found in the 1600 and 1700 degrees Fahr. samples, as shown in Fig. 1. These percentages were checked by running the colorimetric carbons again. As a conclusive proof of the correctness of these figures, graphite carbons were run and subtracted from the total carbon, giving the figures shown in Table I. This result was a surprise, since all of the literature on this subject had inferred that the combined carbon would decompose in increasing amounts with rise of temperature.

The same behavior was found when all of the samples of cast iron No. 2 had been analyzed, as shown by the data, in Table II and curves Fig. 2. The percentages of combined carbon at 1500, 1600 and 1700 degrees Fahr. were all checked by the colorimetric method and by obtaining the percentage of graphitic carbon by the combustion method.

As a final corroboration of these results, a piston composed of cast iron No. 2 was quartered, and great care was taken to obtain a representative sample by drilling. The four quarters were heated for one half hour at 1500, 1600, 1700 and 1800 degrees Fahr., respectively. After heating for one half hour at the various temperatures analyses were made of the original sample and of each of the heat treated pieces with the following result:

Temperature degrees Fahr.	Original	1500	1600	1700	1800
Combined Carbon	0.44	0.22	0.26	0.30	0.29

These percentages checked very closely with the figures obtained in the earlier analysis of cast iron No. 2.

Discussion and Conclusions

The data obtained were used to plot curves, using temperature as abscissa and per cent combined carbon as ordinate. Curves were drawn for half hour periods up to three hours. By referring to the curves (Figs. 3 and 4), it is seen that the maximum amount of graphitic carbon is precipitated in both No. 1 and 2 at 1400 degrees Fahr. Very little increase is noted by heating longer than one half hour (not more than 0.04 per cent), so that the result of longer heating for pieces of the cross section used would not warrant the

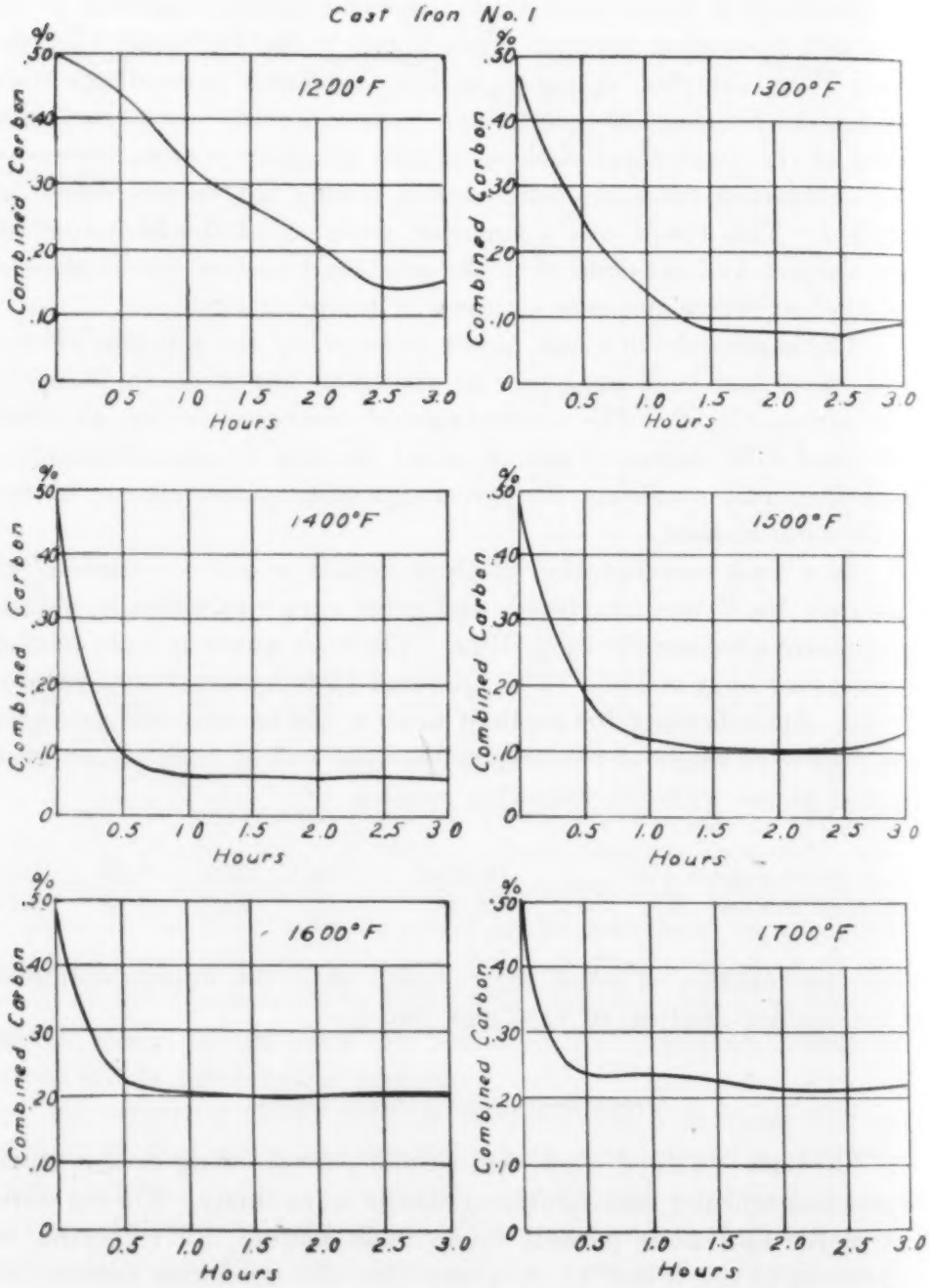


Fig. 1—Cast Iron No. 1. Showing a Gradual Decrease in the Combined Carbon Up to a Temperature of 1400 degrees Fahr. and then an Increase in the 1500, 1600 and 1700-degree Fahr. Samples.

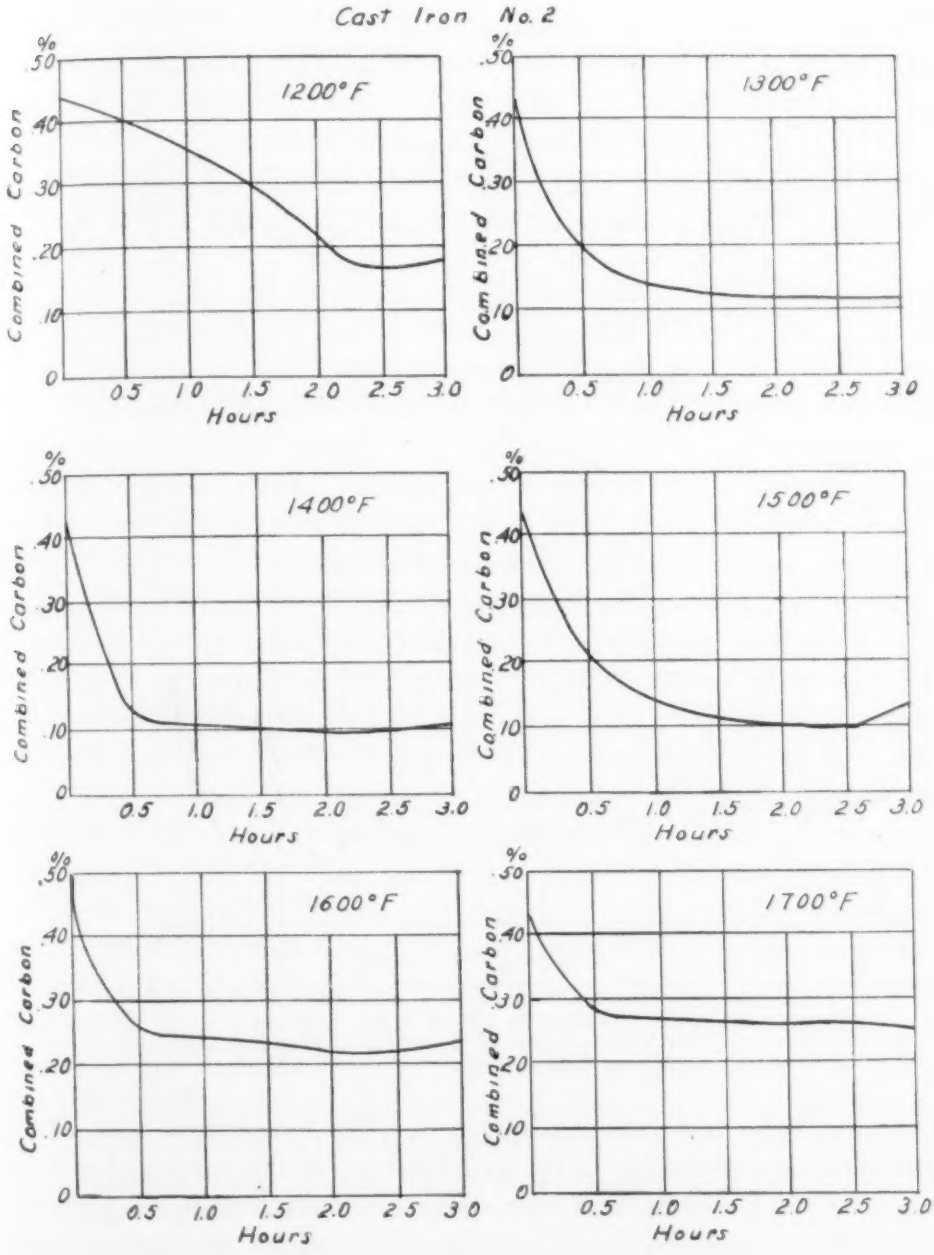
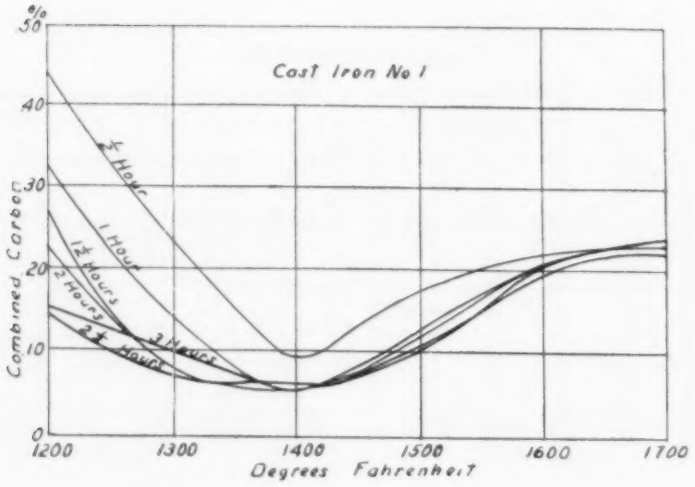


Fig. 2—Cast Iron No. 2. Showing a Gradual Decrease in the Combined Carbon Up to a Temperature of 1400 degrees Fahr., and then an Increase in the 1500, 1600 and 1700 degree–Fahr. Samples.



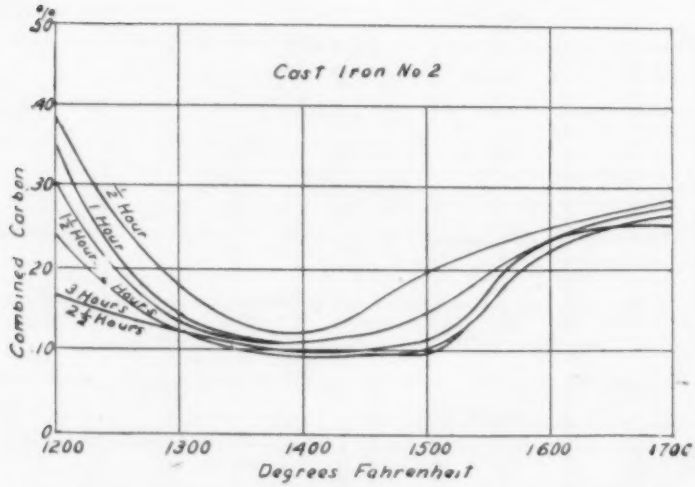


Fig. 3—(Upper) Curves Showing the Effect of Heat Treatment on Combined Carbon in Cast Iron No. 1.

Fig. 4—(Lower) Curves showing the Effect of Heat Treatment on Combined Carbon in Cast Iron No. 2.

increased time and expense incurred. The element of time is an important consideration in the graphitizing of the combined carbon in any given piece of cast iron. Up to a temperature of 1400 degrees Fahr., long periods of heating will produce the same amount of graphitization as heating to 1400 degrees Fahr. for short periods of heating. On heating the 5/32-inch thick pieces used in this experiment, for one half hour, a uniform heat was obtained in them, which resulted in practically all of the precipitation possible at the temperature. It is unlikely that as much graphite would be formed in less than one half hour, since more of the graphite formed when

the pieces were heated for one hour. A shorter period of heating would not permit the crystals to readjust themselves and relieve the strains in the metal. This is one of the major purposes of the annealing and should always be taken into consideration.

When thicker pieces are to be heat treated, it would be possible to bring them up to heat quickly by using a higher temperature, and then lowering the temperature and keeping it there for half an hour.

Silicon does not have a marked effect on the graphitization, as shown by these experiments, although several writers have stated that it materially aids graphitization in white cast iron.

The one and one-half hour up to three hour curves of cast iron No. 2 show as much graphite thrown out at 1500 degrees Fahr. as at 1400 degrees Fahr. This may be due to the presence of the greater amount of silicon, but if this were true, the same results should appear on the one half-hour and one-hour curves.

The metallographic examination showed that the graphite particles were more numerous and larger in the heat treated pieces. The pieces of cast iron No. 2 heated at 1300 degrees Fahr. for one half, one, and one and one half hours had a combined carbon content of 0.24, 0.14 and 0.08 per cent, respectively, (Figs. 5, 6, 7). The graphite in these pieces showed a gradation in size and quantity from small in the 0.24 per cent to large in the 0.08 per cent. It was easily seen that the pieces contained different amounts of graphitic carbon, but after examining a large number of pieces, it was evident that no close value for the increase of graphitic carbon could be obtained by optical methods. The graphite structures seemed to have swollen, due to the fact that the free carbon produced by the dissociation was drawn into position alongside of the already existing plates of graphite. The pieces heated at 1700 degrees Fahr. showed a smaller amount of graphite present than the 1400 degrees Fahr. pieces, (Fig. 8, 9) which also confirmed the analyses.

The metallographic examination also showed that the formation of graphitic carbon is not propogated from the edges of the center as Shüz has stated. The flakes of graphite in the center of the piece were much larger than those at the edge after the piece had been heat treated (see Figs. 10, 11). Shüz stated that on large castings the precipitation is propagated from the edge. This

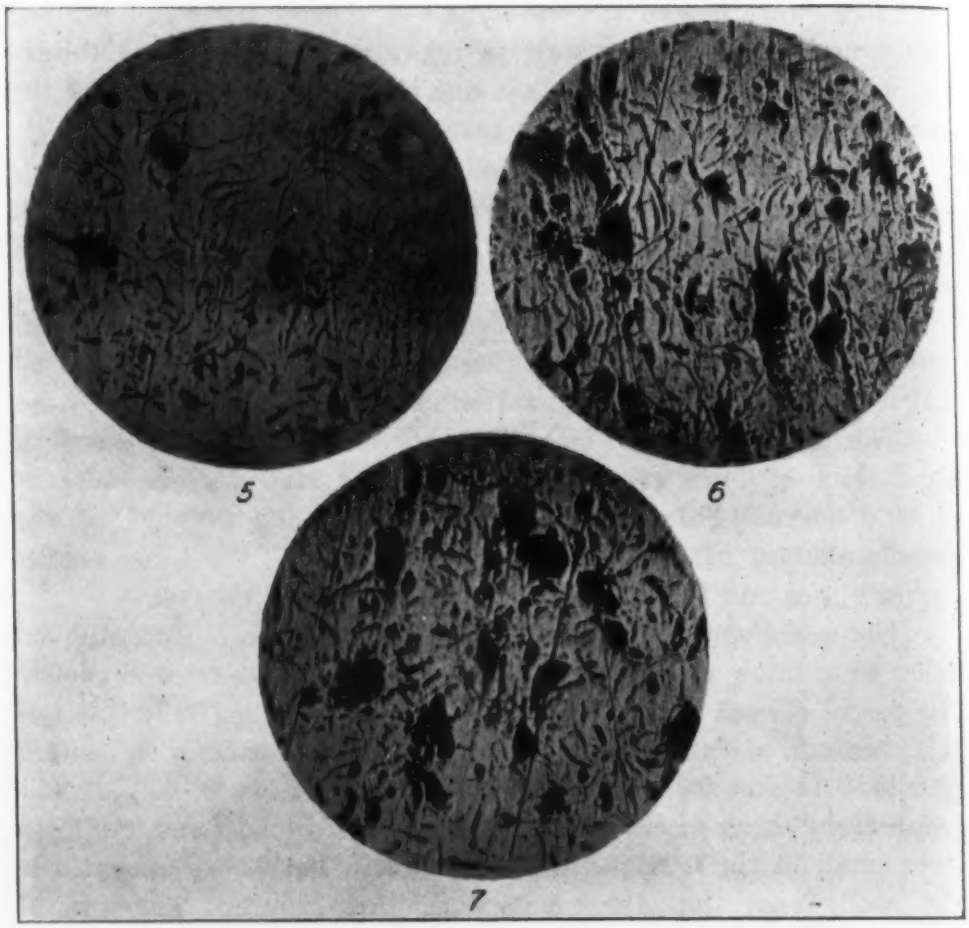


Fig. 5—Photomicrograph of Cast Iron No. 2 Heated for ½ Hour at 1300 degrees Fahr., 0.24 per cent Combined Carbon, 130x.
Fig. 6—Photomicrograph of Cast Iron No. 2 Heated for 1 Hour at 1300 degrees Fahr., 0.14 per cent Combined Carbon, 130x.
Fig. 7—Photomicrograph of Cast Iron No. 2 Heated for 1½ Hours at 1300 degrees Fahr., 0.08 per cent Combined Carbon, 130x.

may be true if the whole piece is not allowed to obtain a uniform temperature, but in the small pieces used in this investigation the reverse seems to be true. A large number of the heat treated pieces were examined and in every case a greater amount of graphite was found at the center of the piece than at the edges, which shows that the graphitization is more complete at the center than at the edges. This is not desirable, since the surface is to be machined and should be softer than the core.

Except in the case of the pieces of cast iron No. 1 heated at 1400 and 1500 degrees Fahr., little change was noticed in the total carbon. The pieces of cast iron No. 1 heated at 1600 degrees Fahr.

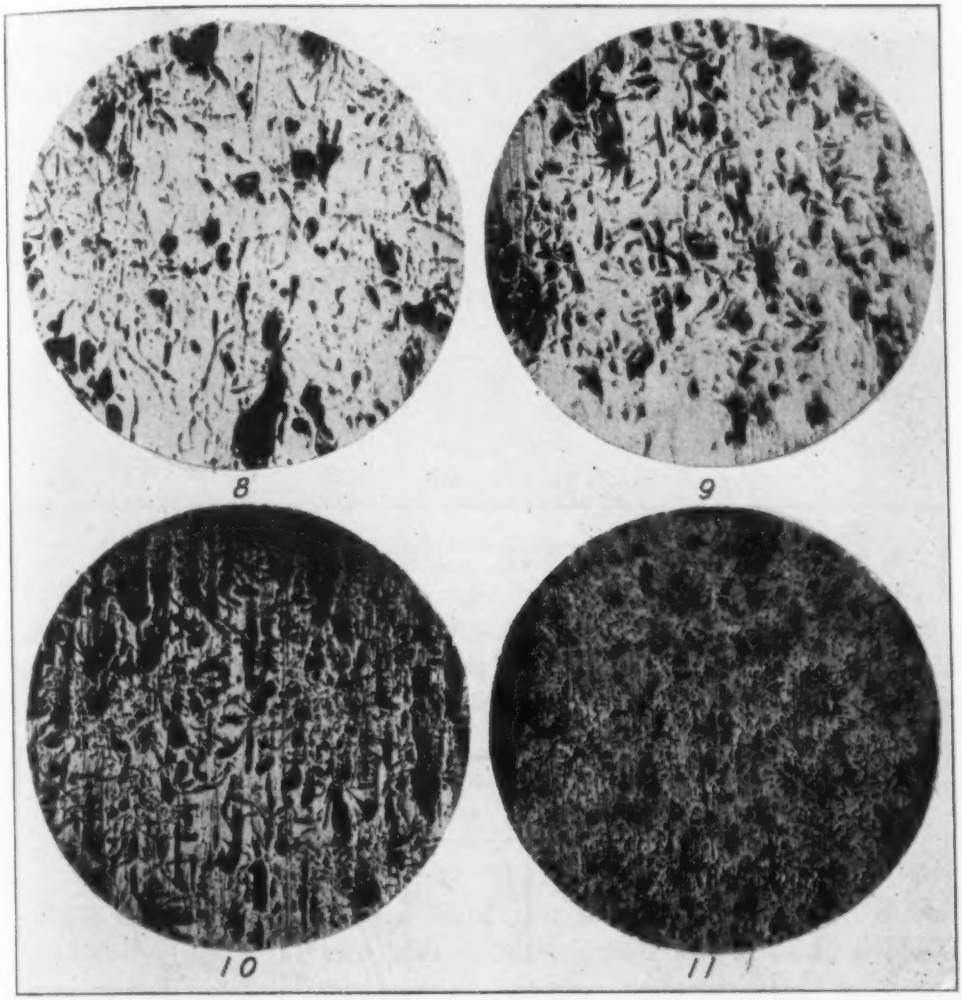


Fig. 8—Photomicrograph of a Piece of Cast Iron No. 1 Heated for ½ Hour at 1700 degrees Fahr., Showing a Smaller Amount of Graphite than at 1400 degrees Fahr., 135x.

Fig. 9—Photomicrograph of a Piece of Cast Iron No. 1 Heated for 3 Hours at 1700 degrees Fahr., 135x.

Fig. 10—Photomicrograph of the Center of a Piece of Cast Iron No. 1 Heated for 1 Hour at 1400 degrees Fahr., 130x.

Fig. 11—Photomicrograph of the Edge of the Same Piece Showing the Difference in Graphitic Carbon, 130x.

showed a gradual increase of total carbon. The pieces of cast iron No. 2 which were heated in the furnace with these pieces did not show a gradual increase, so that this change of total carbon could not be attributed to the furnace atmosphere. Since both of the cast irons showed a small and irregular variation of total carbon, it is not possible to attach any significance to these changes.

Although the two cast irons used in this experiment (Figs. 12 and 13) were of widely varying carbon and silicon content, in the

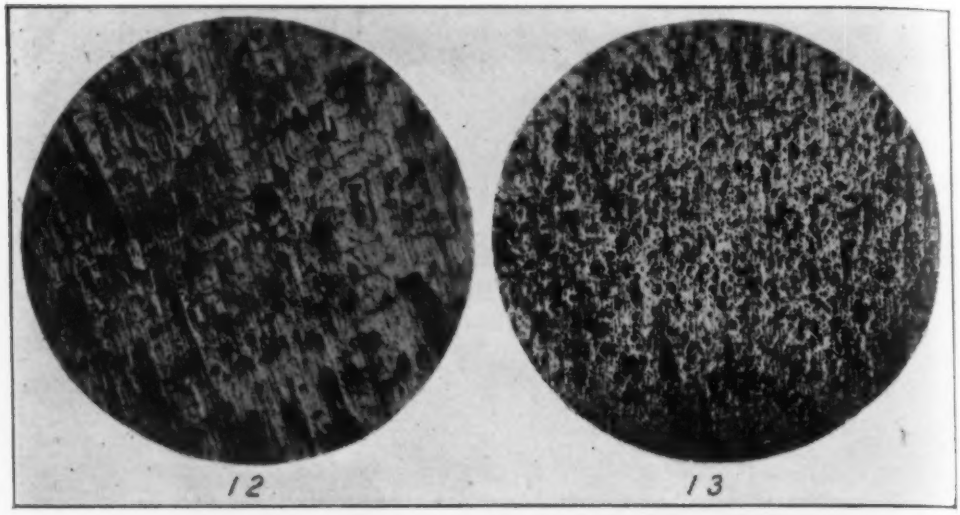


Fig. 12—Photomicrograph of Cast Iron Before Annealing, 130x.
Fig. 13—Photomicrograph of Cast Iron No. 2 Before Annealing, 130x.

curves obtained by the heat treatment for equal lengths of time, there was never more than a 0.04 per cent variation in the combined carbon. Since the maximum graphite content gives the softest cast-

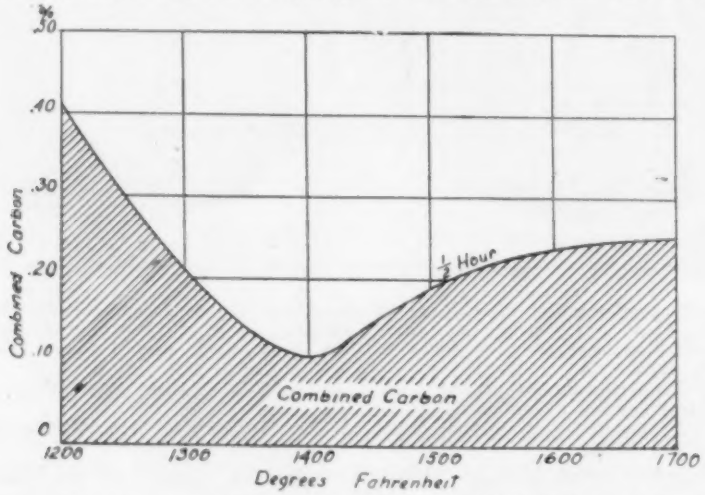


Fig. 14—Curve Showing Change of Combined Carbon in Gray Cast Iron When Heat Treated. Silicon 1.75-2.70 per cent, Carbon Total 3.25-3.52 per cent, Combined 0.43-0.50 per cent.
Note—Curve Holds for Cast Iron up to ⅜ Inch Thick.

ing the practical man is interested in knowing what will happen to the given cast iron when heat treated. Accordingly a curve has been drawn (Fig. 14) taking the average of the combined carbon values for cast irons No. 1 and No. 2 heated for one half hour, this represents the changes which will occur in cast irons ranging from

3.52 per cent carbon and 1.75 per cent silicon, to 3.24 per cent carbon and 2.70 per cent silicon. This curve will hold only to 0.03 per cent combined carbon and for pieces of 3/8 inch cross section. For larger work, a longer time of heating will be required to produce the same results.

Table III

Effect on Hardness by Annealing an Automobile Piston Cast Iron No. 2

Treatment		Rockwell "C" Hard Spot	Rockwell "C" Rest of Piston	Scleroscope Hard Spot	Scleroscope Rest of Piston
As Cast	Ave.	41	34	52	44
	Max.	44	36	56	45
	Min.	39	33	49	42
Annealed	Ave.	29	22	38	30.2
1400° Fahr.	Max.	31	26	40	31
½ Hours	Min.	27	20	36	30

Table III shows the effect of annealing on the hardness of cast iron No. 2.

A Theory of Graphitization in Gray Cast Iron

It is the belief of the writer that if a piece of gray cast iron were heated at 1200 degrees Fahr. for one half hour, then raised to 1300 degrees Fahr and heated for one half hour, raised to 1400 degrees Fahr. for one half hour, etc., the changes in the combined carbon would be as indicated in the curves of Figs. 3 and 4.

The compound Fe_3C is metastable and the reaction is reversible.

$$Fe_3C \rightleftarrows 3\,Fe + C$$

The gray cast iron consists of a matrix containing among other things, Fe_3C and graphite, and as it is heated, the Fe_3C begins to decompose into iron and graphite. Up to a temperature of 1382 degrees Fahr. the iron presnt is in the form of alpha iron which can dissolve the graphite only to a limited extent. Consequently at 1382 degrees Fahr. a minimum amount of Fe_3C should exist. (If analysis had been made at intervals of 20 degrees, this result would undoubtedly have been obtained.) At temperatures below 1382 degrees Fahr., a longer period of time would be required to bring

about the degree of graphitization obtained at 1382 degrees Fahr. Between 1382 degrees Fahr. and 1580 degrees Fahr. the iron is present as beta iron, which has the property of dissolving carbon to a limited extent. Consequently, some of the beta iron would redissolve graphite and cause the reaction to go to the left and keep it from going as far to the right, as in the case of the alpha iron, the result being more combined carbon present. Above 1580 degrees Fahr. the iron is in the form of gamma iron, which dissolves the carbon to a still greater extent and causes the reaction to go to the left. Although on cooling it is true that the iron goes through these stages again, even with air cooling, the drop in temperature from 1600 or 1700 degrees Fahr. to about 800 degrees Fahr. is very rapid and prevents the graphite from forming again. The reaction requires time, as is shown by the fact that heating for one hour at 1400 degrees Fahr. produces more graphite than heating for one half hour.

Summary

1. The maximum resolution of combined carbon in gray cast iron, into graphitic carbon, occurs at 1400 degrees Fahr. when the cast iron is heated for one half to three hours.

2. The degree of graphitization does not increase with a rising temperature. See diagram Fig. 14.

3. Silicon does not have a marked effect on the graphitization produced by heating gray cast iron.

4. The graphitization produced is more complete at the center of the piece than at the edges.

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DETERMINING THE PROPORTIONAL LIMIT OF STEEL

By Bengt Kjerrman

Abstract

In multiple screw tensile testing machines eccentric pull on the specimens is frequently experienced, and involves a source of error especially when determining the proportional limit by means of Martens mirror extensometer.

By providing the specimen with loosely jointed extensions, the distance between the jaws of the machine may be increased and the misalignment reduced. Tests have shown a good agreement of the deflections of the two mirrors when this method was used.

In order to obtain the correct proportional limit from load-deflection data the author proposes the method of calculating the elongation of the specimen corresponding to one load increment of about 1 or 2 kilograms per square millimeter (1422 to 2844 pounds per square inch), assuming for steel a modulus of elasticity of 28,400,000. The proportional limit if not clearly detected otherwise may be considered reached as soon as the observed increments of elongation exceed the calculated.

In a test the limit thus found was the same, whether the load had been increased in many (11) or in few (3) steps, the final load increments in both cases being the same.

THE apparatus most frequently used in Sweden to determine the proportional limit of steel is the Martens' mirror extensometer. It is not, however, the author's intention at this time to describe or discuss the apparatus itself but instead to give his experience in preparing and arranging the test piece and extensometer and his suggestions as to where to place the proportional limit when the test is completed and the record ready.

Proportional Limit

When the proportional limit is to be determined, two opposite lines of the test piece are used for measuring the elongations. By this method it is most frequently found that the corresponding

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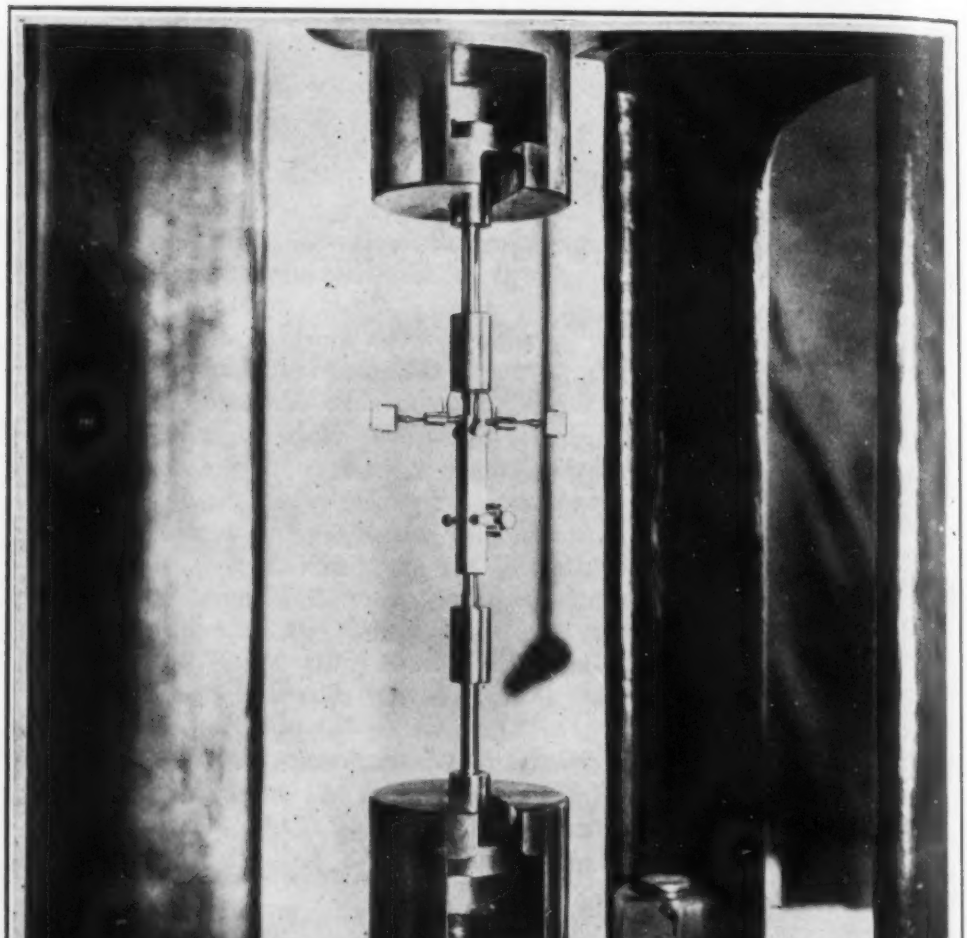

Fig. 1—The Set-up with the Marten's Extensometer in Position.

values from these lines are different and that the difference will increase during the whole test. This difference is most pronounced if the testing machine has four pulling screws and less pronounced if only one screw or a plunger is used. The cause of the error is due to the fact that the machine does not pull exactly through the center line of the test piece. It has been the writer's experience that it is impossible to get an ideal machine for this purpose.

In order to reduce the error as much as possible, the author, developed, after some experiments, the following arrangement. Instead of clamping the test piece directly in the moving head

of the machine it was screwed into two small cylinders of hardened steel. The cylinders were threaded on both ends. On the opposite end to that of the test piece is screwed a steel rod which is fitted with its other end into the clamp of the machine. By this arrangement is obtained, using the ordinary test length, a much longer "test piece" built up from five different parts. The screws do not fit the threads tightly and thus they will allow a little movement for alignment. The set-up with the Martens' mirror extensometer placed in position is shown in Fig. 1.

In order to show the difference between the two arrangements, the following tests were performed using the same steel. The steel was hot-rolled to 7/8-inch round and not heat treated. A test piece having a 6-millimeter (1/4-inch) diameter was turned out for each test. The analysis of the steel was:

C	Mn	Si	P	S
0.75	0.46	0.182	0.021	0.014

The test length for the mirror extensometer was 50 millimeters (2 inches). (See Table I.)

Table I
Deflections due to Various Loading

OLD ARRANGEMENT.					NEW ARRANGEMENT.				
Load, Pounds	Readings Left	Right	Total	Difference	Load, Pounds	Readings Left	Right	Total	Difference
2,200	1000	1000	2000	..	2,200	1000	1000	2000	..
11,000	1300	1041	2341	341	11,000	1155	1175	2330	330
12,100	1331	1054	2385	44	12,100	1179	1193	2372	42
13,200	1359	1069	2428	43	13,200	1203	1210	2413	41
14,300	1386	1086	2472	44	14,300	1229	1230	2459	46
15,400	1411	1102	2513	41	15,400	1250	1249	2499	40
16,500	1439	1121	2560	47	16,500	1271	1269	2540	41
17,600	1465	1146	2611	51	17,600	1294	1290	2584	44
18,700	1490	1167	2657	46	18,700	1314	1310	2624	40
19,800	1520	1190	2710	53	19,800	1336	1333	2669	45
20,900	1555	1217	2772	62	20,900	1359	1359	2718	49
					22,000	1381	1386	2767	49
					23,100	1410	1420	2830	63

The maximum difference between the readings on the two mirrors using the old arrangement was 338 and using the new arrangement only 20. The most important part of it is, however, that the proportional limit itself must be put at the wrong place by using the old arrangement.

The usual way to decide where to put the proportional limit is to calculate the average of the elongation for one step in the increase of the load and to determine the load where the elonga-

tion for one step is more than ten per cent higher than this average value. This gives for the old arrangement 750 kilograms (1650 pounds) and for the new arrangement 900 kilograms (1980 pounds). The corresponding areas for the two test pieces are 0.043 and 0.044 square inches. Consequently the proportional limit is in the first case 27 and in the last case 31 kilograms per square millimeter (38,400 and 44,100 pounds per square inch) respectively. The difference is about 13 per cent. The poorest arrangement also gives a slightly lower modulus of elasticity, 29,600,000 in comparison with 29,700,000 for the better arrangement.

The method mentioned above for the determination of the location of the proportional limit very often gives, in the writer's opinion, wrong results. This occurs especially when the elongations gradually increase for each step. In order to correct these difficulties, the author has developed the following method which has given good results for uniformity. The elongation of the specimen for one load increment is calculated on the basis of a modulus of elasticity of 28,400,000.

If the proportional limit is not obvious from the test data, it may be considered reached as soon as the observed increment in elongation exceeds the calculated. This method gives in the two present cases the same result but in many other cases it is very helpful. The method will, as mentioned before, also help to give much more uniformity in determining the proportional limit than the other method.

The new arrangement of clamping the test pieces is also of some importance for the determination of the other properties. The yield point is much easier to determine because of the more uniform axial pull and the tensile strength, elongations and contraction of area all seem to increase a little. The complete results of the tests are shown in Table II.

In order to investigate whether the speed by determining the proportional limit had any influence on the results the following tests were performed on a hot-rolled steel of the composition:

C	Mn	Si	P	S
0.84	0.34	0.172	0.030	0.016

The steel was an acid open-hearth steel rolled to 15 millimeters round. The test-pieces were cut to 10 millimeters round.

Tests No. 1 and No. 2 were made in the ordinary way. The initial load was 500 kilograms (1100 pounds). The increments

Table II

Measuring Physical Properties of the Same Material by the Old and New Method

Method	Mod. El.	Prop. limit	Yield p.	Tensile S.	Elongation, 10 diam.	Per cent 5 diam.	Contr. Area
Old		27 kg/mm²	41.0 kg/mm²	87.9 kg/mm²	10.5%	13.3%	22%
	29,600,000	38,400 lbs./sq. in.	58,500 lbs./sq. in.	125,000 lbs./sq. in.			
New		31 kg/mm²	41.8 kg/mm²	88.4 kg/mm²	10.5%	14.3%	23%
	29,700,000	44,100 lbs./sq. in.	59,500 lbs./sq. in.	125,600 lbs./sq. in.			

were 500 kilograms up to 2000 kilograms and thereafter 100 kilograms. The proportional limit was located at 2700 kilograms in both cases.

Test No. 3 was made very slowly. The initial load was 500 kilograms and all the following increments 100 kilograms with a little rest of about 1 minute between each addition. The proportional limit was at 2700 kilograms.

Test No. 4 was made very rapidly. The initial load was 500 kilograms and the next increase extended to 2600 kilograms and was reached in a few seconds. After that the intervals were 100 kilograms. The proportional limit was at 2700 kilograms. The complete results were:

Test	Mod.El.	Prop.l.	Yield p.	Tensil.s.	Elongations,	per cent	Contr.
		lbs./in.²	lbs./in.²	lbs./in.²	10 diam.	5 diam.	%
1	30,000,000	49,800	62,400	132,200	10.0	13.6	24
2	30,000,000	49,800	62,400	132,000	10.2	14.0	24
3	30,000,000	49,800	61,600	131,700	10.3	14.0	24
4	30,000,000	49,800	61,800	130,900	10.0	13.8	24

Summary

A new arrangement of holding tension test pieces has been described. This arrangement is particularly useful when determining the proportional limit. It not only gives more correct results but it makes the whole test more convenient to perform because of the very uniform movement of the mirrors. The arrangement has also a certain influence on the other properties determined in a tensile test. A new method of determining the location of the proportional limit has been suggested.

A NEGLECTED PHENOMENON IN HEAT TREATMENT

By Birger Egeberg

Abstract

Quenching temperature is generally determined in relation to the critical point in heating. This method is justified in cases where the Ac and Ar points are close together. Many chromium-nickel steels, however, show a considerable difference between the critical points and it is believed that this fact is not generally considered.

By quenching a piece of steel, in which there is considerable difference between the Ac and Ar points, at a temperature close to the Ar point rather than the Ac point, the advantages of the lower quenching temperature are gained. Maximum hardness and tensile strength with suitable elongation are obtained and it is believed that less dimensional change takes place and that hardening cracks may be eliminated.

A LARGE number of steels in common use show a decided depression of the critical point upon cooling. Such steels are the chromium-nickel steels of the automotive industry. How much this depression amounts to will be seen from Fig. 1, where the heating and cooling curves of an air hardening chromium-nickel steel are plotted. This shows that the difference between the two critical points is about 700 degrees Fahr.

When heat treating steels of this type, no consideration is made of the large hysteresis. The steel is heated to a temperature well above the upper critical point and quenched in oil or air, depending upon the composition of the steel. For the air hardening steel the quenching temperature is in the vicinity of 1550 degrees Fahr., which is 800 degrees Fahr. above the Ar transformation point.

The quenching temperature is generally determined in relation to the critical point on heating, because this relation has an influence upon the strength and the toughness of the quenched steel and this method is entirely justified in cases where the critical points on heating and on cooling are close together. In steels,

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however, where the Ac and the Ar points are far apart, as in the air hardening chromium-nickel steels, it might be worth while also to consider the relation between the quenching temperature

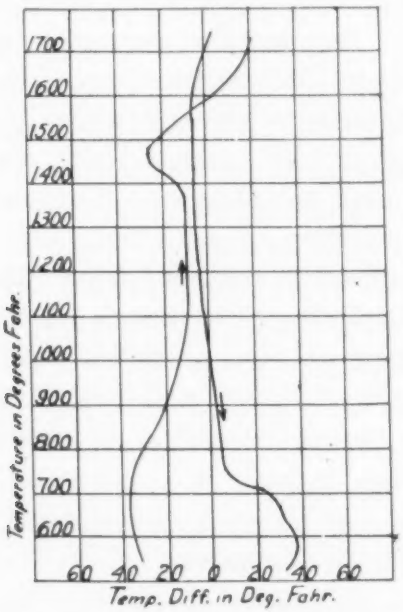

Fig. 1. Heating and CoolingCurves of an Air Hardening Chromium-Nickel Steel.

and the critical point on cooling. This relation might have considerable influence upon the hardening results especially in regard to toughness, warpage and internal strains that might cause cracking of the steel.

It is the object of this article to report briefly the results of experiments made with an air hardening chromium-nickel steel of the following approximate analysis:

	Per Cent
Carbon	0.30
Silicon	0.20
Manganese	0.40
Chromium	1.50
Nickel	4.50

Considerable difficulty was experienced in hardening hollow rolls and rings having a wall thickness of approximately 5 to 6 inches, used for hot rolling various shaped articles of soft Bessemer steel. The rolls were heated to 1550 degrees Fahr. and quenched in oil, as air cooling of this large size did not give the desired hard

ness. Many of the rolls cracked and in order to investigate the possibility of a quenching temperature closer to the Ar point, the following experiment was undertaken.

Standard tensile test pieces were made and were heated to 1525 degrees Fahr. Two samples were removed from the furnace and cooled in quiet air. The furnace was at that time shut off and the remainder of the samples allowed to cool down with the furnace until a temperature of 1300 degrees Fahr. was reached. At this temperature, two more samples were removed and quenched in air. After a further drop in temperature to 1110 degrees Fahr. another set of samples was removed from the furnace and so on down to 750 degrees Fahr. (the critical point) at which temperature, the last two samples were quenched. All samples were then ground to 0.505 inch diameter and one of each treatment was pulled in a tensile testing machine. A tabulation of the results is given in Table I.

Table I

Physical Properties

Quenching temperature Degrees Fahr.	Tensile Strength-lb. sq. in.	Per cent Elong. in 2 inches	Red. of Area per cent	Brinell Hardness
1525	239,000	1	17.3	495-512
1300	244,000	10	26.7	512
1110	237,500	13	34.6	495
930	242,500	13	38.7	495
840	245,000	14	44.7	500
750	229,000	8		512-460

All samples heated to 1525 degrees Fahr. and slowly cooled with the furnace to the temperature given in the first column and quenched in air at that temperature.

It will be noticed that gradually decreasing the quenching temperature from 1525 to 840 degrees Fahr. causes a steady increase in elongation and in reduction of area, whereas the Brinell hardness and tensile strength remain fairly constant until a temperature of 750 degrees Fahr. is reached. At this temperature the critical point on cooling is reached, causing a drop in hardness and in tensile strength. The toughness figures at this point have also dropped due to an uneven hardness, the middle of the tensile

test pieces being harder than at the punchmarks caused by the retarded cooling effect of the larger heads. Due to this effect the sample cannot stretch equally over its whole length, this explains why it breaks with less elongation than that which would correspond to its tensile strength.

The remaining samples, one from each of the foregoing treatments, were tempered at 480 degrees Fahr. and pulled. The results were nearly constant. No matter which of the previous heat treatments the sample had undergone it always showed, after tempering to 480 degrees Fahr. a tensile strength of approximately 240,000 pounds per square inch elongation of 15 per cent in two inches, reduction of area of 45 per cent, Brinell hardness number of 495,-477. This indicates that the difference found between the samples in Table I is probably caused only by strains set up during air quenching of samples from the higher temperatures and that such strains are not introduced, or are at least of comparatively small magnitude, when the steel is slowly cooled to near the Ar point before it is quenched. The low magnitude of the strains can be explained by less dimensional change taking place when quenching from the low temperatures.

When heat treating pieces of large dimensions or of intricate shape, the advantage of the low quenching temperature is evident. By dropping the quenching temperature of the steel from 1525 or 1550 degrees Fahr. to a temperature in the neighborhood of the thermal critical point of cooling, it is possible to obtain the maximum hardness and tensile strength that the steel is capable of giving, combined with 13 to 14 per cent elongation, by which hardening cracks are eliminated. When quenching from a temperature of 1550 degrees Fahr. or a similar temperature above the Ac point the steel will not be any harder or stronger and the elongation will be so low that hardening cracks are likely to develop. Besides, there is the question of warpage or volume change. It is anticipated that the low quenching temperature will give less dimensional change than the high quenching temperature. This part, however, was not investigated thoroughly and it shall, therefore only be stated that the steel, when given the low quench, comes in the class with the so-called non-changeable steels. Further, the possibility of quenching articles of slender shape, at a temperature

below visible red when the steel is stiff enough not to bend when handled, is of undoubted value in many cases, especially when such treatment of the steel in question is able to develop a hardness anywhere from 512 down to 228 Brinell, depending upon the following tempering temperature.

It is felt that the described hardening method may also be of value for other steels where a considerable thermal hysteresis exists and the method can also be applied to such steels when case hardened. If difficulties due only to cracking, exfoliation or volume change have to be guarded against and the question of bending caused by handling at a red heat does not need to be considered, two furnaces would probably be of advantage; one furnace where the steel is heated to the initial temperature above the Ac point and from which the steel is transferred into a second furnace kept at a constant, lower temperature in the neighborhood of the Ar point, where the steel is kept until it has acquired this temperature and is ready for the quench. It was found that a cooling time of four hours from 1525 degrees Fahr. to the desired quenching temperature was of no influence upon the results. Any longer cooling time was not experimented with.

IRON-CARBON-VANADIUM ALLOY FOR BRINELL BALLS

(Continued from Page 26)

temperatures it is a hard solid solution in itself, not involving martensitic formation.

G. W. QUICK: It forged very nicely hot. It was appreciably harder in the heat treated condition than it was in the annealed state. On the Rockwell C-scale there were some 20 to 30 points difference.

E. C. BAIN: After all, that is not a difference comparable to that which one would expect if it were the production of tool steel martensite by quenching.

DR. H. W. GILLETT: We would have followed it out in a good deal more detail had it turned out that the balls were of more value in testing very hard steel. We were rather misled by the previous literature. We expected, since everyone had pointed out that the main trouble must be due to deformation, that if permanent deformation were reduced, much better Brinell tests should be possible on very hard materials, but when we did get a ball which had only half the permanent deformation of the Hultgren ball, we found no real difference in the Brinell numbers obtained with the two. Thus it appears that the error is not so much due to the small remaining amount of permanent flattening—as to elastic distortion. In other words, it looks as though we had almost reached a dead wall until a material can be found of much greater modulus of elasticity in compression than steel; something not too brittle to be usable as a Brinell ball.

THE DECOMPOSITION OF THE AUSTENITIC STRUCTURE IN STEEL — Part VI.

Proposed Theory for the Hardening and Tempering of Steels

By Oscar E. Harder and Ralph L. Dowdell

Abstract

In this part of the paper the authors have attempted to put the results of their investigation into the form of a proposed theory for the hardening and tempering of steel. This theory discusses, in addition to the decomposition of the austenite structure, the reactions on heating steels above the critical points, the changes which take place while holding at temperature, changes which take place at various rates of cooling, and, finally, the changes which take place on reheating hardened steels to various temperatures below the critical for different lengths of time.

THE theory proposed in the following paragraphs is based largely on the results of this investigation but to some extent on the researches of others and to a still lesser extent upon the theoretical considerations. The theory has been proposed to cover the changes taking place during heating, holding at temperature, cooling at various rates, aging, and reheating after quenching such as tempering or drawing.

This theory seems to be in agreement with the fundamental principles involved and to account for the phenomena observed in a more satisfactory manner than any other theory that has come to the writers' attention.

1. Heating

During the heating of a sample of steel the phases tend to approach the more stable equilibrium condition. In the case of the carbide this results in the formation of spheres and the increase in the size of the particles. As soon as the critical temperature is

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A paper presented before the eighth annual convention of the Society, Chicago, September 20 to 24, 1926. Of the authors, Dr. R. L. Dowdell is assistant professor of metallography and Dr. O. E. Harder is professor of metallography, University of Minnesota, Minneapolis.

reached there is a solution reaction between the ferrite and the carbide resulting in the formation of a new phase, the solid solution austenite, which has a different space lattice. This new phase must first form crystal nuclei of the new lattice which continue to grow to a maximum at any given temperature, which maximum is larger as the temperature is increased. The solution of carbide is a progressive reaction the rate of which depends upon the character of the solvent and solute, the size of the solute particles, and the temperature. X-ray evidence indicates that the carbon atom goes into the gamma iron space lattice, but does not replace iron atoms in the lattice.

2. Holding at Temperature

A eutectoid steel, for example, which has been heated just above the critical point for a short period of time may show, when quenched, undissolved carbide, showing that insufficient time was allowed for the solution reaction to go to completion. The presence of another phase in contact with the austenite solid solution retards the grain growth of the austenite. This is found to be true for the presence of either ferrite or carbide.

During the holding of a steel at temperatures above the critical point the grain growth of the austenite begins as soon as the lower critical is reached and grows somewhat slowly as long as other phases are present and then more rapidly after the condition of a single phase is obtained. The rate of growth then further increases as the temperature increases. Abnormally large sized grains may be produced under condition of strain.

Nonuniform composition may be obtained in a single-phased austenitic system if the time of holding is insufficient to provide for complete diffusion of the carbon. This may result in lower carbon in areas where ferrite has just gone into solution or in higher carbon contents in areas where carbides have just gone into solution.

3. Cooling

During the cooling of a steel from above the upper critical point, equilibrium conditions would require a general reversal of the above reactions. Only an infinitely slow rate of cooling would produce equilibrium conditions and as a result all commercial rates of cooling steel produce unstable conditions. These condi-

tions result in the delayed appearance of precipitation and of transformation of phases. In the extreme condition, particularly with steels of high alloy content, it is possible to obtain at room temperature completely austenitized structures which on X-ray analysis show the gamma iron pattern only.

Slower rates of cooling or less stable austenites result in a more or less complete recrystallization from gamma to alpha. The mechanism of recrystallization from gamma to alpha necessarily involves the formation of crystal nuclei of the alpha pattern and their growth. The further growth of these nuclei depends upon the temperature at which they are formed, the character of the material, etc. If they are formed at extremely low temperatures the particles even when brought back to room temperature may be too small to give an X-ray diffraction pattern. Austenitic structures which have been retained at room temperature may be caused to recrystallize by subjecting them to extremely low temperatures such as liquid oxygen, by mechanical stressing at room temperature or at liquid oxygen temperatures, or by reheating to a more favorable temperature for the recrystallization.

If the transformation takes place comparatively near the lower critical point on cooling and the rate of cooling in this range of temperature is slow, the alpha particles may show considerable growth and the carbide particles may coalesce into particles of their own space lattice of sufficient size that they are clearly distinguishable under the microscope and have sufficient stability to be resistant to acid etching.

When the rate of cooling is somewhat faster than that indicated above, but slower than the rate required to produce maximum hardness, there is some growth in the ferrite particles and a slight coalescence of the carbide into its own space lattice, the particles of which are so small in size as to not be clearly distinguishable under the microscope at the usual high magnifications. These particles of carbide have insufficient stability to resist the attack of acid etching reagents. The result observed is a darkening of the etched specimen. This apparently may be attributed to the decomposition of the carbide giving free carbon,[1] an etching out of the small carbide particles from the ferrite groundmass or an attack on ferrite surrounding the carbide particles. Probably the

[1]Heyn and Bauer: *Journal*, Iron and Steel Institute, Vol. 79, p. 226, 1901.

observed phenomenon is due to a combination of the three conditions. The microstructure is generally known as troostite.

For a steel quenched from any given temperature above the upper critical the hardness increases as the rate of cooling increases. For steel quenched in the same medium from different temperatures above the upper critical point, the hardness increases first as the temperature increases but finally reaches a maximum and for a still higher quenching temperature shows a decrease in hardness. This decrease in hardness may be attributed largely to the coarsening of the grain at the high temperature and the resulting smaller amount of slippage in the austenite during cooling. This structure of the steel in the condition of maximum hardness is known as martensite. In order to produce this martensitic structure it is necessary to cool at such a rate that the recrystallization takes place at a comparatively low temperature.

Probably the maximum hardness results from the minimum possible size of alpha particles providing there is complete absence of the gamma phase. The directions of the needles found in martensite indicate that they follow the octahedral planes in the austenite. A consideration of the austenite space lattice shows the octahedral planes to be those of highest atomic population and greatest interplanar distance and therefore the planes of easy slippage according to recent work[2] on the correlation of crystal structure with the slippage in metals under stress.

This indicates that the austenite previous to its recrystallization has been subjected to sufficient stress to cause its slippage along the octahedral planes. Slippage along these planes would produce disarranged atoms and therefore favor the condition for the beginning of the recrystallization to the alpha lattice.

This investigation has shown that these needles can be produced by cooling an austenite to the temperature of liquid oxygen, by stressing austenite at room temperature, or by stressing it at room temperature and then cooling to the temperature of carbon dioxide snow. It appears that all of these treatments produce sufficient stress in the austenite to cause slippage and therefore start the recrystallization. It has also been possible to produce martensite needles by reheating certain specimens and apparently in those particular cases there was sufficient stress

[2]Davey: TRANSACTIONS, American Society for Steel Treating, Vol. 6, 375, 1924.

produced in the pieces to cause slippage before a sufficiently high temperature was reached to bring about the austenite to troostite transformation which is the one more frequently observed on reheating an austenite.

It further appears that if the slippage in the austenite takes place at a comparatively high temperature on cooling, there is first recrystallization followed by growth of alpha particles and coalescence of the carbide particles so that the structure etches dark with acids (Dark needles). Such structures do not show maximum hardness and a certain amount of tempering action is indicated.

From the results of X-ray analyses of martensitic structures it is concluded that martensite has the alpha lattice with the carbon atoms retained within the lattice as a supersaturated solution but not replacing the iron atoms.

From the above consideration it appears that the greater amount of austenite in steels when oil-quenched as compared with the same steels when quenched in water may be attributed to the stresses produced in the oil quench being insufficient to produce slippage in the austenite grains.

It has been found possible in the case of some alloy steels to produce wholly austenitic structures by oil quenching. This indicates that the metastable austenite may continue to exist as such providing sufficient stress is not encountered to cause the slippage and therefore a disturbance in the system which causes it to revert to the more stable phase.

This same line of reasoning seems to account for the observed fact that in the case of certain steels, martensite is found on the outside zone while the core or an iner zone is found to be austenitic. In the case of those steels which are martensitic throughout it appears that the stressed zone has migrated during the process of quenching and with the migration of this stressed zone inward more martensite is formed. Because of the increase in volume accompanying the gamma to alpha transformation, tensional stresses should favor the reaction while compressional stresses should oppose it.

Experiments have shown hardened steels in the quenched condition to be in tension in the center and in compression at the surface. This seems to agree with the theory of the migration of

the stressed zone and to connect it up with the formation of martensite throughout the specimen.

From the consideration of the results obtained in this and other investigations, it appears that as the rate of cooling increases the structures produced may be pearlite, sorbite, troostite, or austenite, providing there is not sufficient stress encountered to cause slippage in the austenite grains. This consideration, however, is usually not obtained in the commercial quenching operations and as a result at least some martensite is present. It would, therefore, seem that if the recrystallization from gamma to alpha has not taken place until a comparatively low temperature is reached, austenite will be retained unless there is slippage resulting in the formation of martensite.

Moderate stresses which cause slippage in some areas may result in the formation of some martensite while other areas less stressed may remain austenitic, thus producing both austenite and martensite in the same specimen. Extremely high stresses with general slippage would seem to be the condition for the formation of what is known as a wholly martensitic structure. Under the microscope this commercial martensite still has small patches between the white needles which appear to be undecomposed austenite.

The hardness of martensite produced by quenching may be largely acounted for by the following reasons:

1. The intra-atomic forces in the martensite.
2. The extremely fine grain size resulting from the recrystallization from gamma to alpha at a temperature far below its normal recrystallization.
3. The saturation or the supersaturation of the martensite with respect to the carbon atoms within the alpha lattice.
4. The distortion of the space lattice of alpha and some residual gamma caused by stress.
5. The actual interference to slipping which would be caused by the formation of the martensite needles.

4. Aging

During the aging of a quenched steel it may reasonably be expected that a specimen containing both martensite and austenite may show some continuation of the recrystallizing process. This

should result in an increase in hardness, an increase in volume and a heat evolution. It does not appear that a wholly austenitic steel will transform to martensite on aging at ordinary temperatures.

From the results of X-ray measurements it is indicated there is always a hysteresis effect in the space lattice dimensions of steels after changes in temperature. A quenched steel therefore should have an expanded parameter which on aging should approach the equilibrium dimensions. This reaction should cause a decrease in the volume of the steel, a heat evolution, and probably a slight increase in hardness.

5. Tempering

During the reheating of an austenitic steel either a martensitic or a troostitic structure may be produced. It appears that the stress in the specimen is the controlling factor and if a sufficient amount of stress is encountered on heating to produce slippage in the austenitic structure, martensitic needles may be produced. Both the light and the dark needles have been observed. It appears that if the slippage takes place below the temperature at which martensite tempers, the needles will be light-colored, but if it takes place at a temperature where the martensite tempers, the needles will be dark-colored. The more frequently observed phenonenon, however, in the tempering of an austenitic specimen is a gradual darkening of the etched structure without the formation of needles with definite boundaries. This darkened structure may take the form nodular troostite or it may be without any characteristic appearance except the general darkening. It is the generally observed relation that it requires a higher temperature to break down an austenitic structure than that required to darken a martensitic structure.

The tempering of an austenite involves recrystallization from the gamma to the alpha lattice. This reaction alone must produce the fine-grained ferrite and because of the lower density the alpha material must have an increase in volume. If the transformation is to martensite it is believed that the alpha phase is not only extremely finely crystalline but that it is in addition a supersaturated solid solution. If the transformation is to a troostite the recrystallization is accompanied by more or less complete separation of the carbon into carbide particles. Since this transformation is a higher temperature reaction, more growth of the alpha particles

may be expected which should result in a decreased hardness and a decreased volume. The maximum hardening due to the carbide particles should be associated with the minimum size of particles and the maximum number of particles, a condition which has been called by Jeffries and Archer, "critical dispersion." Obviously then further growth of the size of the ferrite particles and carbide particles by coalescing should result in decreased hardness and increased density.

The tempering of martensite appears to be first the breaking down of a supersaturated solid solution in which the carbon is rejected from the alpha lattice and collects into carbide particles. On further heating either for long periods of time or at higher temperatures it appears that these two reactions may continue simultaneously. At first the predominating reaction is the rejection of the carbon from the alpha solution, probably as carbide. As this approaches completion the growth of the ferrite and carbide particles comes to be the predominating reaction.

The mechanism of the growth of carbide particles in contact with the alpha lattice is thought to be through the alpha lattice as the solvent. The solubility of carbon in the alpha lattice is known to be quite low but is undoubtedly higher for finely divided carbide than for particles of larger size. Such a condition makes possible the growth of the larger particles at the expense of the smaller ones. As previously mentioned there is a size in the carbide particle which is attacked by etching reagents. That size of most rapid attack is associated with the structure troostite. On still higher draws there is a continued growth of the carbide particle until it becomes of such size that it can be observed under the microscope. Its stability toward acid attack increases and it appears light-colored after etching. Still further drawing, such as to a temperature just below the critical temperature simply gives an oportunity for the continuation of the reaction just outlined resulting in an extremely soft steel with completely spheroidized carbide.

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DISCUSSION

Written Discussion by Zay Jefferies, Cleveland. The mechanism of hardening and tempering of steel as proposed by Harder and Dowell is very gratifying. The writer agrees in the main with the ideas put forth by these authors and believes that these conceptions are in harmony with observed data.

It might be pointed out, however, that the proposed cause of room temperature aging, namely, that the observed changes are due to a contraction in the space lattice of iron due to a volume hysteresis occasioned by the previous rapid cooling, does not seem very satisfying. The idea suggested by Mr. Archer and the writer and held by Scott and others, that the changes produced on room temperature aging are generally due to the precipitation of cementite seems to account for the reduction in volume, evolution of heat, decreased electrical resistivity and increase in hardness and furthermore this idea seems to be consistent with sound theory.

The extension of the ideas on the relation between permanent deformation and the transformation of austenite is very welcome. This work seems to harmonize in general with the suggestions of Bain, Scott and Hoyt on this subject. It would seem, however, that, instead of assuming that permanent deformation is the cause of the transformation of austenite, the other alternative should be given its proper weight, namely, the transformation of austenite under conditions not requiring previous deformation, causes permanent deformation. In other words the ''amount of stress,'' encountered on heating is partly produced by the transformation itself.

The writer wishes to congratulate the authors of this paper and looks forward to the publication of their further researches.

D. J. MCADAM, JR.: There is just one question that I should like to ask of some of those who are familiar with the X-ray method of analysis. How does the sensitivity of microscopic analysis compare with the sensitivity of X-ray analysis, as a means of determining microstructure? I notice that for one of his figures the author drew the conclusion that the martensite was decomposing into troostite. It seems to me that microscopic examination is not a sensitive method of determining whether or not martensite is decomposing into troostite.

O. W. ELLIS: I was sorry not to hear Mr. Dowdell's reading of the paper, as Mr. Dowdell and I talked it over in part some little while since, at which time I mentioned to him the results of certain work that has been

recorded in a recent volume of the proceedings of the Royal Society by Andrew and certain collaborators on the tempering of austenitic and martensitic steels. These experiments consisted in the measurement of the change in the electrical resistivity of austenitic steels and of martensitic steels with time at the tempering temperature, and, so far as I remember, their conclusions were as follows:

If an austenitic steel were tempered, the austenite transformed into troostite without intermediate formation of martensite, so long as the temperature was held constant; if however, at any time during the tempering period the temperature was allowed to fall, then there was production of martensite during the fall of temperature. If a martensitic steel were held at a certain definite temperature for a prolonged period, the martensite, of course, would be transformed directly into troostite. Possibly Mr. Dowdell could tell us whether he has been able to connect up these two series of experiments (his and Andrew's) since our discussion of the same at Pittsburgh.

DR. S. L. HOYT: I regret I did not hear the entire presentation. I read over this Part VI which has been preprinted and my feeling then was that I should like to have all of the information which is contained in their complete work, because this paper seems to be largely a summary and conclusion, and that really makes it a little difficult to offer any adequate discussion. Furthermore, some of these points which are taken up here will be discussed in my own paper which comes tomorrow morning, and it does not seem worth while to say today what I intend to say tomorrow.

One point that interested me in particular was what happens to austenite when reheated. It has always seemed to me that austenite in carbon steels simply breaks down into troostite, although quite a number of experimenters assume that austenite changes into martensite and then into troostite. The experimental data on which that is based is simply that the volume change indicates that martensite is formed. Now, to me, those data are not sufficient, for the simple reason that the density of austenite itself is sufficiently high to account for a volume change from austenite into troostite. In other words, it is not necessary to assume that martensite forms in order to account for the increase in volume. You can do that if you simply assume that troostite forms.

Now, if you assume that troostite forms, the direct microscopical evidence is readily accounted for, because under the microscope the evidence is that austenite changes into troostite and not into martensite. Fraenkel and Heymann, in considering this point, had to assume that the martensite is so fine grained that we cannot determine its grain size; in other words, we have to sidestep the question.

Now, in some of the low alloy steels, particularly those which have been described by Grossmann and Bain, probably, or, in fact, undoubtedly, show a change from austenite to martensite. This is confirmed by the microscopical evidence, the volume change and by the hardness change. In plain carbon steels, the hardness change is the reverse of what you would expect if austenite changes to martensite. So we ought clearly to distinguish between the transformation from austenite to martensite and from austenite to troostite on tempering. I do not feel that that has been done sufficiently in the past.

In the summary which the authors make here, in which they account for the hardness of martensite, it seems to me that what they do is to include most everybody's opinion.

R. L. DOWDELL: There are practically no references, but in the resume of the literature everyone has due credit.

S. L. HOYT: Well, in this way you ought to satisfy everybody, unless they ask you to evaluate the various reasons. In fact, I think it would be very well for the authors to do that; having gone over the field and considered it, and having seen worth while to suggest that there are five contributary causes to the hardness of martensite, it might be a good idea to give us those which they think are the real causes, that contribute most largely to the hardness of martensite.

In the paper tomorrow morning there is one idea which I know I shall not have time to consider in great enough detail. I refer to quantitative data, which I think we do not consider as we should. We should adopt more and more, if we can, the methods of the physical chemist in studying reaction velocities, temperature coefficients and heats of reaction, etc., because whatever picture we may set up, it must at least be consistent with quantitative evidence. It is a comparatively simple matter to set up a picture which is consistent qualitatively with the evidence, but before we have a theory, the picture must be consistent with the quantitative evidence. For example, the authors use one of the ideas of the slip interference theory, that of the formation of cementite particles by diffusion of carbon through the alpha iron lattice, and so on. Such a process would be initiated by incubation, and continued by diffusion of the carbon atoms through the alpha iron lattice. Certain definite consequences would follow from such an assumption as that.

For instance, I would expect an incubation period such as we have during the solidification of a metal from a molten state, and so far as I know, no one has ever observed an incubation period in the tempering of steel. One would be confronted at once with this difficulty when considering quantitative data. You should account for the absence of an incubation period.

Secondly, a diffusion phenomenon which occurs over the temperature ranges in question should be accompanied by a heat of reaction of a certain order of magnitude, which, expressed in calories per gram mole, would be around a few thousand. Now, from the experimental data of Fraenkel and Heymann, the heat of that reaction is 28,000 to 30,000 calories per gram mole, or of an entirely different order of magnitude. In other words, your diffusion picture is not consistent with quantitative data.

Thirdly, if you follow the effect of temperature and determine the temperature coefficient of the reaction, you will find that it runs on the average of 2.4 between the temperature range of 70 degrees Cent. and about 200 degrees Cent. The temperature coefficient of a diffusion phenomenon lies between 1 and 1.5. Again we find the picture which Jefferies and Archer have advanced and which is accepted, apparently, by the present authors, is not at all consistent with the quantitative data.

Now, that line of argument might be continued. I am advancing it here simply with the suggestion that we attempt to utilize more and more quantita-

tive data in establishing a theory of the quenching of steel. Tomorrow morning I hope to extend this a little and apply it to the volume changes or anomalous dimensional changes which occur during the quenching and tempering.

E. C. BAIN: I should like to take about two minutes to refer to a discussion of this paper which I have prepared. In the main, it has to do with the important point which Dr. Hoyt just called to our attention. Does austenite ever, upon reheating, change to martensite, or does it always go directly to troostite? In certain alloys judging from what I have observed I believe that we must conclude that it may change to something which looks very much like martensite before it goes over to troostite.

I should like to refer to some photomicrographs which I have prepared. Unfortunately, these were prepared for another purpose in which we did not wish to study the minute structure, but at any rate here is an austenite tempered at successively higher temperature. It will be seen that even at a 930-degree Fahr. temper some transformation has taken place beginning in almost every instance at grain boundaries and that it has grown still more voluminous with increase in temperature until after a 1110-degree Fahr. temper the transformation has proceeded well toward the center of every grain. Close examination of this transformed structure would certainly result in the guess that it is martensite for it resembles extremely closely the martensite of low carbon steels. It might almost be regarded as characteristic martensite.

However, when tempered at 1200 degrees Fahr. the regions immediately adjacent to the grain boundaries begin to develop a new material which is certainly standard troostite. The troostite extending from the grain boundaries is in every case formed from the coarsely acicular martensite-appearing material.

The photomicrographs used here were taken at 250 diameters magnification and they are all made from a chromium steel containing about 24 per cent chromium and 0.50 per cent carbon. An oil-quench retains the entire metal in uniform polyhedral austenite which shows the characteristic twinning of gamma iron solid solutions. With slower cooling replacing the quench or with reheating after the quench we may obtain all degrees of decomposition of this austenite. It appears then very doubtful, indeed, that we are justified at this time in making the assertion that austenite once preserved at room temperature changes only to troostite and never to martensite, for it is my belief that the microstructures observed in these samples which were photographed are sufficiently definite and conclusive as to point to at least one certain exception to such a general rule.

Inasmuch as the allotted time for this paper has nearly elapsed I would ask Mr. Dowdell to give his closure on the discussion.

R. L. DOWDELL: That is quite a volume of material to discuss at this time. I think I will take the questions up in order, because I have had a chance to look at the written discussion by Dr. Jeffries. In answering the discussion by Dr. Jeffries, we are quite pleased, of course, to note that he is in general agreement with us.

As far as this question of permanent deformation is concerned, we think

Austenite Showing the Changes Which Have Taken Place When Tempered at Various Temperatures.

that we have evidence here that permanent deformation is the cause of the transformation of austenite to martensite, and in that case we have some ring specimens which we have investigated at room temperature and actually started the decomposition of austenite to martensite.

Now, this other question, of course, is of a great deal of importance. When once this transformation of austenite to martensite has been started, we believe, of course, that the transformation itself will produce still more stress, and still more deformation. This is perfectly logical and a very fine suggestion but we think the greatest part in starting the transformation is the question of the original slip. In other words, it will not slip without a little start, and that start seems to do the trick.

In regard to the changes produced on room temperature aging, it may be that the precipitation of carbide takes place. We believe that it does but we have no special proof that it does. But we do know there is a hysteresis effect in the lattice parameter which will account for all of the other phenomena, so we have tried really to stay within our bounds and not really go very much over the mark.

Dr. McAdam's question I think was about the same as Dr. Bain's question, in a way, as to what happens when austenite decomposes. We have performed some tempering tests over long periods of time, for instance, one month at 212 degrees Fahr. and two months at 150 or something like that. In the low alloy steels, when we have these stable conditions, it appears that austenite goes to troostite so far as the microscope is concerned. Now, by martensite we are inferring, of course, a very hard white needle structure that is in relief and is not etched out. If we have conditions of unstable equilibrium, for example, if we heat up in tempering at a very fast rate, we are likely to have both martensite and troostite formed and everything else comes in where we have such an unstable condition. We have tried to study this from the condition of really stable equilibrium as closely as we could do it.

I am very sorry after I spoke to Mr. Ellis this summer that I did not have a chance to look up the reference he referred to. We did not have a chance to check that up so we really can not say anything on that question at this time.

In regard to some of Dr. Hoyt's questions, of course, it appears that the real physical phenomena should be very seriously considered, there is no question about that. However, we have some evidence on densities which was not mentioned at all here. Apparently austenite under stable conditions breaks down to troostite. We have nothing on the diffusion reaction so far as that goes, but it seems that none of the reactions that have been dealt with by Fraenkel and Heymann or others checked at all. We had a lot of difficulty in trying to find out as to just what was happening and did not have an instrument delicate or sensitive enough to perform that test, but we intend to go ahead and really establish this on a little more fundamental proof.

Nonferrous Section

ALUMINUM BRONZE

By Jerome Strauss

Abstract

The aluminum bronzes or aluminum-copper alloys rich in copper have been known for a number of years and have been the subject of frequent researches since the early part of the 19th century. Extensive commercial application has been of more recent origin and at present is growing at an extremely high rate.

The present paper is a review of the constitution, mechanical properties and resistance to corrosion of these aluminum-copper alloys with and without the addition of other elements. It is intended to provide those who up to the present time have been largely interested in steel and its heat treatment, with a survey of a portion of the nonferrous field in which mechanical properties, heat treatment practice and other features are closely allied to those of some common ferrous products.

An effort has been made to cover the entire useful range of these bronzes but particular stress has been laid upon the properties and practice common to those compositions that have found the widest range of structural uses.

PROVIDED that the accepted scheme of nomenclature recognizes the word "bronze" as applicable solely to alloys in the copper-rich commercially-useful portion of the copper-tin system, then the term "aluminum bronze" is a misnomer. But usage is often the dictator of established practice. And as the foundations for objections have been neither so strong nor so numerous as in the case of the kindred term "manganese bronze," efforts to displace it have not been as frequent and as vigorous as with the latter and the appelation is still sound.

Aluminum bronzes comprise that group of copper-rich aluminum-copper alloys containing from very small amounts up to about 16 per cent of aluminum by weight, with or without appre-

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ciable additions of other elements. Commercially, the bulk of the useful compositions contain from 5 to 11 per cent of aluminum with a few applications of alloys containing as low as 2 per cent and as high as 15 per cent of this element. Among the additional elements, manganese, iron, nickel and zinc are the ones which have been used in greatest quantity. But large percentages of these elements, particularly the latter two, cause the resultant metals to more nearly resemble alloys of copper with those elements. These combinations have long carried other generic terms (cupro-nickel and brass) and thus make the formulation of a sharp boundary to the field of aluminum bronzes, very difficult. Of these complex combinations consideration will be carried only to the point of definitely indicating the direction of change in the properties or to pointing out transitions, but in no case will they be considered as aluminum bronzes when containing more than 25 per cent of elements other than the two basic ones.

There are many properties of the members of this group of alloys that have created a metallurgical interest that should, if it already has not, find its way into the vision of everyone associated with the production and heat treatment of steel and steel products. Some compositions within the range of this discussion are among the strongest of the nonferrous alloys. Among them will be found the only structural copper-base alloys lighter than steel. Of all the nonferrous alloys heat treated commercially to secure increase in strength, only these alloys are subjected to quenching and tempering within the same temperature range as steel, thus involving similar technical practice. One group of alloys formed with a third element possesses ferromagnetic qualities to a high degree though containing no iron, nickel or cobalt, and certain microstructural features are strikingly similar to common structures found in steels. Yet with all these points of similarity the ferrous metallurgist will find equally as many features sharply distinguishing the two groups of metals, thus adding further to the interest.

I. Constitution

a. The Equilibrium Diagram

A portion of the constitutional diagram, after Stockdale (202),[1] is reproduced in Fig. 1. One of the most prominent and inter-

[1]The figures appearing in the parentheses refer to the bibliography appended to Part II of this paper which will be published in August.

esting general features of this system is the extremely small range of solidification, or temperature interval between liquidus and solidus, in alloys containing up to 17.9 per cent of aluminum. This is of technical importance, for the alloys freeze quickly and with-

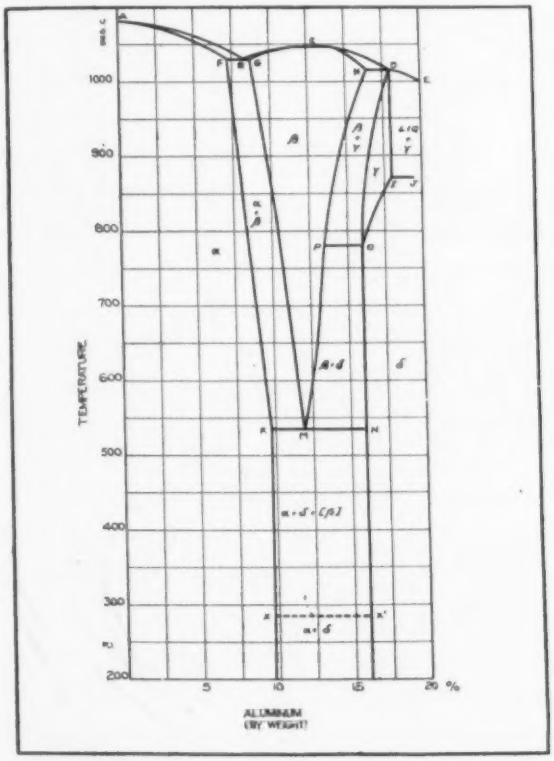


Fig. 1—Copper-End of Aluminum-Copper Equilibrium Diagram (Stockdale)

out great concentration gradients within each primary crystal; the influence of this phenomenon will be referred to again when considering manufacturing operations.

From the copper side of the diagram it is apparent that at atmospheric temperature copper may hold in solid solution up to 9.8 per cent of aluminum and the resultant alloy be composed of a single phase or metallographic constituent. This is described as the alpha solid solution and is a simple solution of aluminum in copper.

In appearance it closely resembles other solid solutions and, in particular, the alpha solid solutions of copper; it forms twinned crystals readily, not only due to working and subsequent reheating but even in the cast state as a result of stresses due to the

casting operation alone. In Fig. 2a this alpha solution is shown after casting and annealing and in Fig. 5c after rolling and annealing; the latter will be observed to be quite indistinguishable from alpha brass (such as 70 copper: 30 zinc) similarly worked and reheated. Constitutionally the alloy remains unchanged if its temperature is raised to as high as 999 degrees Fahr. (537 degrees Cent.) If the temperature is further increased alloys containing 7.5 per cent aluminum and over form a second phase at a temperature somewhere between 999 and 1888 degrees Fahr. (537 and 1031 degrees Cent.). This second constituent is generally regarded as the compound Cu_3Al containing either excess aluminum or excess copper in solution according to the composition of any given alloy; it is referred to as the beta solid solution (it should be noted that in the alloys with less than 9.8 per cent this beta can be Cu_3Al dissolving excess aluminum only). Alloys of 7.5 to 8.5 per cent aluminum, at some temperature within the range noted above, will, due to the decreasing solubility of aluminum in copper with temperature increase, be composed of part alpha and part beta solid solutions. From 8.5 to 9.8 per cent aluminum, the alloys may, with suitable conditions of heating, be converted entirely into the beta constituent (above the line GM). The beta constituent is harder and stronger than the alpha solid solution and thus the retention of beta, stable at elevated temperatures, by rapid cooling offers heat treatment possibilities. Theoretically this effect (partial retention of beta) may be secured above 7.5 per cent aluminum; practically, appreciable strengthening is not observed until about 8.5 per cent aluminum is reached and then only with small sections and high cooling rates.

Above 9.8 per cent aluminum and with less than 11.9 per cent of this element the alloys are composed solely of beta when above temperatures represented by the line GM (according to composition). Upon cooling below this line (slowly) some alpha forms due to increasing solubility of aluminum in copper; as the temperature continues to fall, the amount of alpha increases at the expense of beta until 999 degrees Fahr. (537 degrees Cent.) is reached. At this temperature a transition occurs quite parallel to that of the formation of pearlite from residual austenite (exclusive of the allotropic change), namely a change of the beta solid solution into a eutectoid mixture of the alpha solid solution

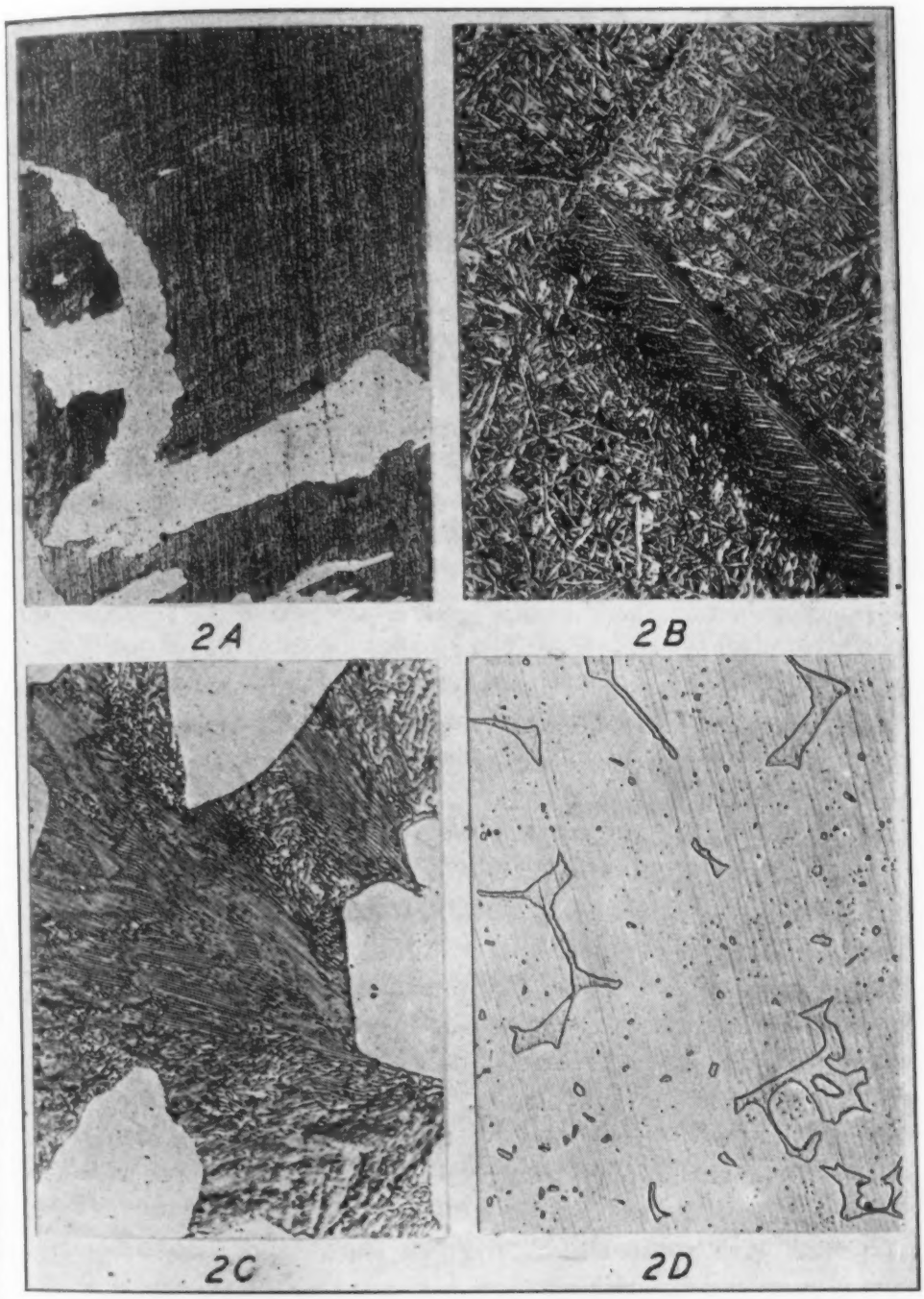


Fig. 2—(a) Alloy Al-8.31 per cent Fe.-2.44 per cent Sand Cast 1-inch thick, Pure Alpha, 100x.
(b) Alloy Al.-10.24 per cent, Fe.-0.28 per cent, 1-inch Rd. Forged Bar, Heated to 1650 degrees Fahr. Water Quenched, Beta and Small Amount of Alpha, 100x.
(c) Alloy Al.-10.24 per cent, Fe.-0.28 per cent, Center of 10-inch Diameter Ingot, as Cast, Alpha and Lamellar Eutectoid, 500x.
(d) Alloy Al.-12.5 per cent, Massive Delta in Alpha Groundmass.

and another solid solution to which the letter delta has been applied. Alloys of composition corresponding to the eutectoid point M (11.9 per cent aluminum) will be composed entirely of beta when above 999 degrees Fahr. (537 degrees Cent.) and entirely of the alpha-delta eutectoid below this temperature (except as referred to below).

Alloys containing over 11.9 per cent and up to 16 per cent of aluminum will, immediately following solidification, be composed of the beta solution but upon further cooling, due to alteration in solubility relationships, they suffer changes of constitution. Alloys of 13.5 to 16 per cent aluminum are, after passing a temperature represented for each individual composition by the line PH, partially converted into a fourth solid solution designated as gamma. On cooling below 1425 degrees Fahr. (774 degrees Cent.) the gamma solution is transformed to delta. Alloys of 11.9 to 13.5 per cent aluminum, however, do not form gamma, the delta solid solution forming directly from a portion of the original beta upon reaching the line MP. On further cooling, all of these alloys when reaching a temperature of 999 degrees Fahr. (537 degrees Cent.) have their residual beta solid solution transformed into the alpha-delta eutectoid; in all of them there remains, of course, unchanged massive delta.

There is then in this portion of the diagram a strong reminder of the metallography of the iron-carbon alloys (always exclusive of allotropic changes). In parallel with proeutectoid ferrite is found proeutectoid alpha solid solution (both relatively soft and ductile) and to correspond with proeutectoid cementite there is proeutectoid delta solid solution (both relatively hard and brittle). The eutectoid is in both cases strong and of ductility intermediate between those of its components. By quenching, the transformation may be suppressed, and by tempering, it may be caused to proceed to a varying but controllable degree. The soft alpha is shown in Fig. 2a and Fig. 5c while in Fig. 2d the hard delta is associated with some alpha; Fig. 2c shows the eutectoid (with some alpha) and its striking resemblance to well-developed pearlite.

The beta component is at low magnifications, acicular in appearance and quite like coarse-grained martensite (see Fig. 2b). At higher power it is seen to be highly twinned. Beta is hard and moderately brittle; on the other hand gamma and delta possess

hardness and extreme fragility as well. Alpha and delta are both golden yellow, the latter somewhat paler; gamma is silvery white and delta has a slight bluish cast.

It should be noted that in the region of composition in which gamma is stable at some elevated temperature, beta has not been preserved by quenching to room temperature as in lower aluminum alloys, due to the speed with which it decomposes to form gamma during rapid cooling.

Stockdale has assumed that the gamma solid solution has Cu_2Al (this contains 17.57 per cent aluminum and there is a minimum in the liquidus and a constant temperature of solidification at 17.9 per cent aluminum) as its base just as beta is regarded as being based upon Cu_3Al. No widely accepted explanation has been forthcoming however for the origin of the delta solid solution.

Reference has heretofore been made to the existence of the alpha-delta eutectoid below 999 degrees Fahr. (537 degrees Cent). Actually some beta always remains unchanged and in a metastable condition, even with fairly low cooling rates. This residual beta decomposes at about 547 degrees Fahr. (286 degrees Cent.) leaving alpha-delta eutectoid either alone or with free alpha or free delta, according to the composition of the alloy.

The inversion at 999 degrees Fahr. (537 degrees Cent.) is subject to hysteresis effects in the same manner as the Al transformation in steel. Braesco (175) found the change on heating to occur over a range of 986 to 1040 degrees Fahr. (530 to 560 degrees Cent.) and its reversal on cooling over a range of 1004 to 932 degrees Fahr. (540 to 500 degrees Cent).

It is well to note that the diagram of Fig. 1 represents Stockdale's earlier work (202). Some changes were made in the upper right portion of Fig. 1, as a result of later study of higher aluminum alloys (265) but even these, due to the extreme difficulty attached to determining the reactions in this zone, are still in dispute. These alloys, above 16 per cent aluminum, are moreover, of no present commercial use, and as they were excluded from the ranges to be covered in this report no further mention of these controversial matters need be made.

(b) Effects of Added Elements

In a single instance only has the metallography of a complete

ternary system containing copper and aluminum been systematically explored; this is the system containing nickel. In a few other instances the high copper corner of the ternary system has been surveyed while for others a few scattered facts are available. A brief summary of the results of these investigations will be given in this section.

Manganese

Manganese up to 10 per cent in alloys containing aluminum up to 11 per cent effects no sharp change in structural features. Manganese enters into the alloy in a manner similar to aluminum, influencing the microstructure in the same direction though to a lesser degree. Based upon Guillet's conceptions of "coefficients of equivalence" and "fictitous compositions" developed in his studies of the copper-zinc alloys, manganese would be expected to be about one twelfth as effective as aluminum in producing structural alteration, such as the change from alpha to alpha plus beta. In his investigations of the copper-zinc alloys, Guillet defined the "coefficient of equivalence" as the numerical value of the added percentage of zinc required to produce in a copper-zinc alloy the same structural change as one per cent of the element under consideration. The "fictitious composition" of a two-component, three-metal brass was described as those percentages of copper and zinc that would yield a microstructure showing the same volume proportions of the two constituents as were actually present in the alloy being dealt with. The "coefficients of equivalence" of various metals as determined for the special brasses have been applied to other copper-base alloys by means of the ratio of the "coefficient" of a third element to that of aluminum, for example, when dealing with aluminum bronzes. These "coefficients" are not absolute and vary somewhat with the actual composition; that is to say, the "additional-zinc" effect of one per cent of aluminum on a 63:37 brass would be slightly different from the effect upon a 55:45 brass. As a first approximation however they have proven of value and their application to true bronzes and aluminum bronzes by the method mentioned have shown the same degree of reliability to result. The introduction of a special constituent due to the third metal, vitiates the use of the "coefficient." From a consideration of one feature of the liquidus surface of the copper-aluminum-manganese system, the

variation in the "coefficient of equivalence" of manganese in aluminum bronzes can be readily inferred. With a constant "coefficient" the eutectic point at 8.5 per cent aluminum and no manganese would be the beginning of a locus of such points, for increasing manganese contents, that would be a straight line (this is the separation of the alpha and alpha plus beta fields); actually it is curved, bending in to 7 per cent aluminum at about 5.5 per cent manganese and out again to 7.5 per cent aluminum at 10 per cent manganese.

Within the range of manganese and aluminum contents already noted, no special constituent due to the manganese is found. The similarity of manganese-free and manganese-bearing alloys exists not only in the "as cast" or "as forged" states but subsequent to annealing or quenching or quenching and tempering as well.

Among the ternary combinations containing manganese, some exhibit magnetic properties; these have excited considerable scientific interest and stimulated much research. There is as yet no generally accepted explanation of the phenomena uncovered and what is more important for the present purpose, no technical application. On this account and also because many of the more magnetic alloys in the group contain more than 25 per cent of manganese, only a brief note regarding them is included here.[2] Prior to their discovery by Heussler in 1904 the only known ferromagnetic substances were iron and its alloys and compounds and nickel and cobalt. Among the alloys in the extreme copper corner of the system those containing roughly, over 14 per cent of aluminum plus manganese, are magnetic. Heussler found that alloys of many metals with manganese or manganese plus copper showed these properties. However, among the most magnetic of these, are a series of alloys of compositions lying close to a line connecting the compounds Cu_3Al and Mn_3Al on the usual triangular coordinates of the ternary system, and believed by some to be solid solutions of these two compounds.

Nickel

On the basis of earlier work with the special brasses Guillet

[2]The literature is replete with references to and researches upon these Heussler alloys. They have been omitted from the appended bibliography as they would constitute a large one, of themselves.

computed (250) in the manner noted above that the "coefficient" for nickel in aluminum bronze was-0.22; that is that each per cent of nickel added to a copper-aluminum alloy affected the structure to the same degree as a decrease of 0.22 per cent in the aluminum. That this "coefficient" is not constant is implied by the position of the liquidus minimum line in the ternary diagram of Austin and Murphy (232); its form is quite similar to that resulting from the presence of manganese. Unlike manganese however, nickel in certain proportions introduces special microconstituents. Both the alpha and the beta constituents appear capable of dissolving nickel without change in appearance but above certain amounts the special constituents have been found by Read and Greaves (100) to appear as follows:

> "A—In 10 per cent aluminum alloys; a greyish-blue constituent which appears in the slowly cooled metal at 5 per cent of nickel but is suppressed by quenching up to 7.5 per cent of nickel. With 10 per cent or more it forms primary crystals which are not removed by quenching.
>
> "B—In 5 per cent aluminum alloys; a constituent which in the slowly cooled metal first appears at 5 per cent of nickel but which is suppressed by quenching from 1652 degrees Fahr. (900 degrees Cent.), until the nickel exceeds 10 per cent. As a secondary constituent this etches brown or bluish but with 15 per cent nickel, what is probably the same constituent forms primary dendritic crystals of a clear blue color which persist after quenching."

The special constituent of the 10 per cent aluminum alloys is shown in Fig. 3a and the primary dendrites of the 5 per cent aluminum high-nickel alloy in Fig. 3b. It is of interest at this point to note that Guillet (101) observed only the alpha solid solution in combinations with small amounts to well over 25 per cent nickel but less than 3 per cent aluminum. Here as in many other instances, the great influence upon the properties of these alloys of small composition changes, is evident.

The secondary constituent of the nickel-bearing 5 per cent aluminum alloys was not described above in any detail. In continuing their studies of these alloys and noting that some were harder on slow cooling than on quenching, Read and Greaves (184) uncovered a very interesting series of alloys, the properties of which will be considered in the sections devoted to the results of mechanical tests. Referring to Fig. 4, the alloys to the right of AB con-

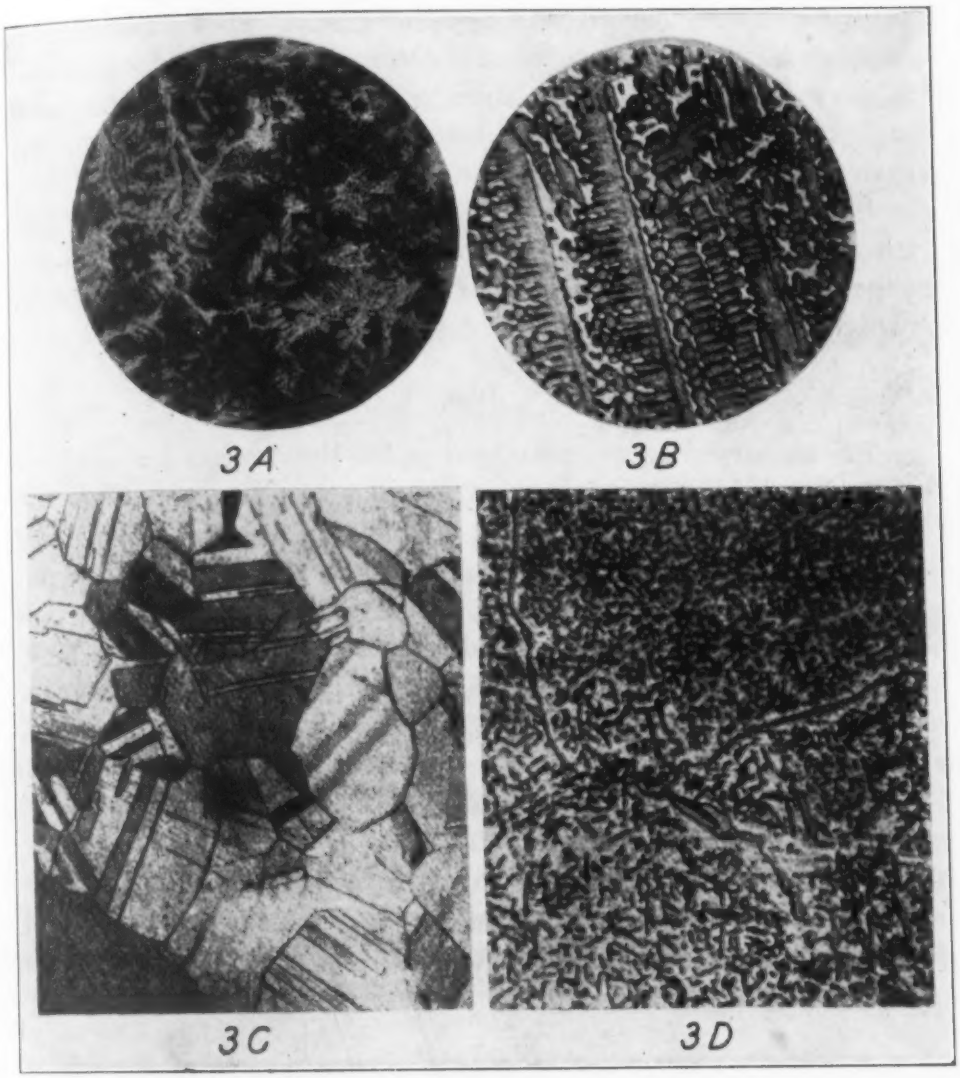


Fig. 3—(a) Alloy Al.-9.92 per cent, Ni.-10.14 per cent, as Chill Cast, Star-Like Special Constituent, 100x.
(b) Alloy Al.-5.20 per cent, Ni.-14.90 per cent as Chill Cast, Dendrites of Special Constituent, 100x.
(c) Alloy Al.-6.93 per cent, Ni.-5.62 per cent, 900 degrees Cent. Water Quenched, Alpha with Special Constituent in Solution, 100x.
(d) Alloy Al.-6.93 per cent, Ni.-5.62 per cent, 900 degrees Cent. Slowly Cooled, Special Constituent Precipitated, 500x. (Read & Greaves.)

tain beta after quenching and are softer on slow cooling than on rapid cooling. But in the alpha zone to the left, it has been found that alloys within the area CDB will on slow cooling precipitate the secondary constituent noted previously, whereas on rapid cooling its separation from the alpha solid solution is suppressed. In Fig. 3c the homogeneous alpha is shown and in Fig. 3d the

separated special constituent appearing after slow cooling. By reheating after quenching, this same constituent reappears in more finely divided form. Here then is an alloy closely resembling duralumin and certain other metallic alloys in respect to the physical changes resulting from quenching and tempering.

Similarly to the ternary system containing manganese, that with nickel shows a series of isomorphous solutions between the compounds Cu_3Al and Ni Al; no strong ferromagnetic properties however were observed in these combinations (232).

Iron

The ternary diagram with iron as the third metal has not been found in published literature. According to Corse and Comstock (124) the special constituent due to the iron appears in quantity when the amount of this added element is 4 per cent but is not present in alloys containing 1 per cent. The present author has not made special experiments to determine the solubility limit but has observed that it varies with heat treatment and aluminum content between about 2.0 and 3.0 per cent. The "coefficient of equivalence" below this amount is according to Guillet (250) 0.15. The iron-bearing constituent appears in the cast alloys as primary crystallytes of nodular form (rosettes) and bluish color that etch blue gray and then successively light and dark brown with acidulated ferric chloride. After working and annealing, the special iron constituent is no longer nodular but round or oval in section as though dissolved and reprecipitated during processing.

Tin

The influence of tin upon the copper-aluminum alloys has recently been carefully investigated by Stockdale (324) although previously covered in less detailed manner by Edwards and Andrew (63). The minimum of the liquidus (8.5 per cent aluminum in the binary system) is moved toward a lower aluminum content with increasing percentage of tin until with 9 per cent of the added element, this point occurs at less than 6 per cent aluminum. It is of interest to note however that with up to 9 per cent of tin, this minimum and also the maximum corresponding to Cu_3Al of the binary system occur at constant atomic proportions of aluminum plus tin (respectively 18 and 25 per cent). With 3 per cent of tin

the constitutional diagram is quite similar to that of the simple binary system; above this addition, there is such complexity particularly near to and on the aluminum side of the eutectoid point (M of Fig. 1) as to preclude their consideration in this paper. Several features, however, are worthy of note: first, tin very greatly increases the range between liquidus and solidus; second, in the

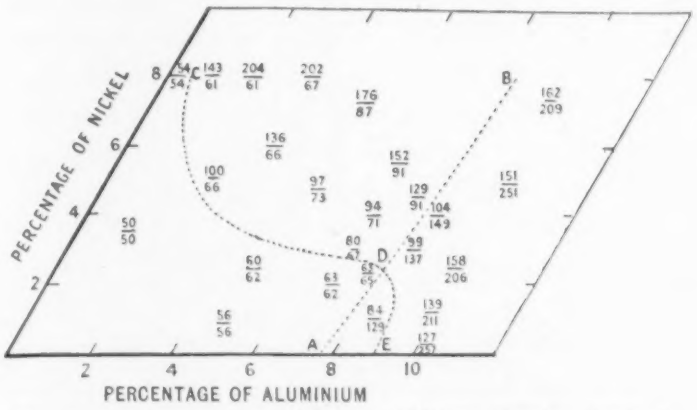


Fig. 4—Corner of Ternary Diagram Al-Ni-Cu Showing Zones of Hardening and of Softening Due to Quenching. (Read & Greaves.)

freezing of some of the ternary alloys no tin is contained in the first metal to solidify; third, the eutectoid transformation temperature is raised markedly in the higher copper alloys but the transformation velocity is reduced; fourth, in some of the higher tin alloys containing over 8 per cent aluminum the eutectoid does not form, being replaced by a constituent similar to beta. No truly special constituent appears in these alloys.

Phosphorus, Magnesium, Cobalt, Silicon and Zinc

Guillet (251) prepared alloys containing up to 0.60 per cent phosphorus and found in those with 0.36 per cent and above a black constituent of rounded outline; his alloys also contained 1.5 to 2.0 per cent of iron and the phosphorus constituent was associated with the characteristic bluish iron-bearing nodules. When substituting up to 3 per cent magnesium for equal weights of aluminum, the same investigator found, even with as little as 0.50 per cent, a special constituent which he assumed to be the compound Cu_2Mg. This new element of the microstructure associated itself with the eutectoid and appreciably altered its character. With only 0.43 per cent of cobalt, Guillet found the same microstructural forms

as in the binary alloys but upon the addition of 0.92 per cent a special acicular constituent appeared and with increasing percentages arranged itself in an intergranular network; he stated that the needles were probably Al_4Co. The influence of one other element has been recorded by this same author—that of silicon. With up to 3 per cent added no special constituent appears and within this range of composition, the "coefficient of equivalence" of 1.66 computed from his work upon the special brasses, applied very well. Above 3 per cent of silicon, the compound $Cu_{19}Si_4$ appeared but this may be retained in solution by suitable quenching; the depth of penetration of hardening, however, appears to be extremely slight in these alloys so that the desired results are often obtainable only on the surface. Stockdale (324) refers to a coarsening of the alpha-delta eutectoid with over 0.50 per cent silicon; this would account for its ill effect upon the ductility of these bronzes. Zinc has received scant attention but work of the author on its addition to alloys containing about 8.7 per cent aluminum and 3.0 per cent iron has indicated that no special constituent forms with as high as 10 per cent of zinc. Under given conditions there appeared to be a coarser eutectoid when zinc was present than when absent thus confirming the findings of Stockdale (324) when adding zinc to binary combinations.

(c) Commercial Alloys

The pure alpha alloys of the binary system are seldom applied in the cast form. As rolled products they are used to a considerable degree. In the cold-worked condition, the structure of a 6 per cent aluminum alloy is shown in Figs. 5a and 5b. Upon annealing, recrystallization and grain growth occur as in other single-phase alloys and twinning takes place in such a manner as to make the metal indistinguishable structurally from the single phase brasses (Fig. 5c.). The introduction of small percentages of iron or nickel or manganese influence the grain size or the recrystallization temperature or both but in its general appearance the metal structure is quite unaltered.

Alloys of the duplex type are extensively used in the cast form, both "as cast" and after heat treatment. In the alloys which "as cast" contain only a very small amount of beta, heat treatment is often applied only to improve low elastic properties

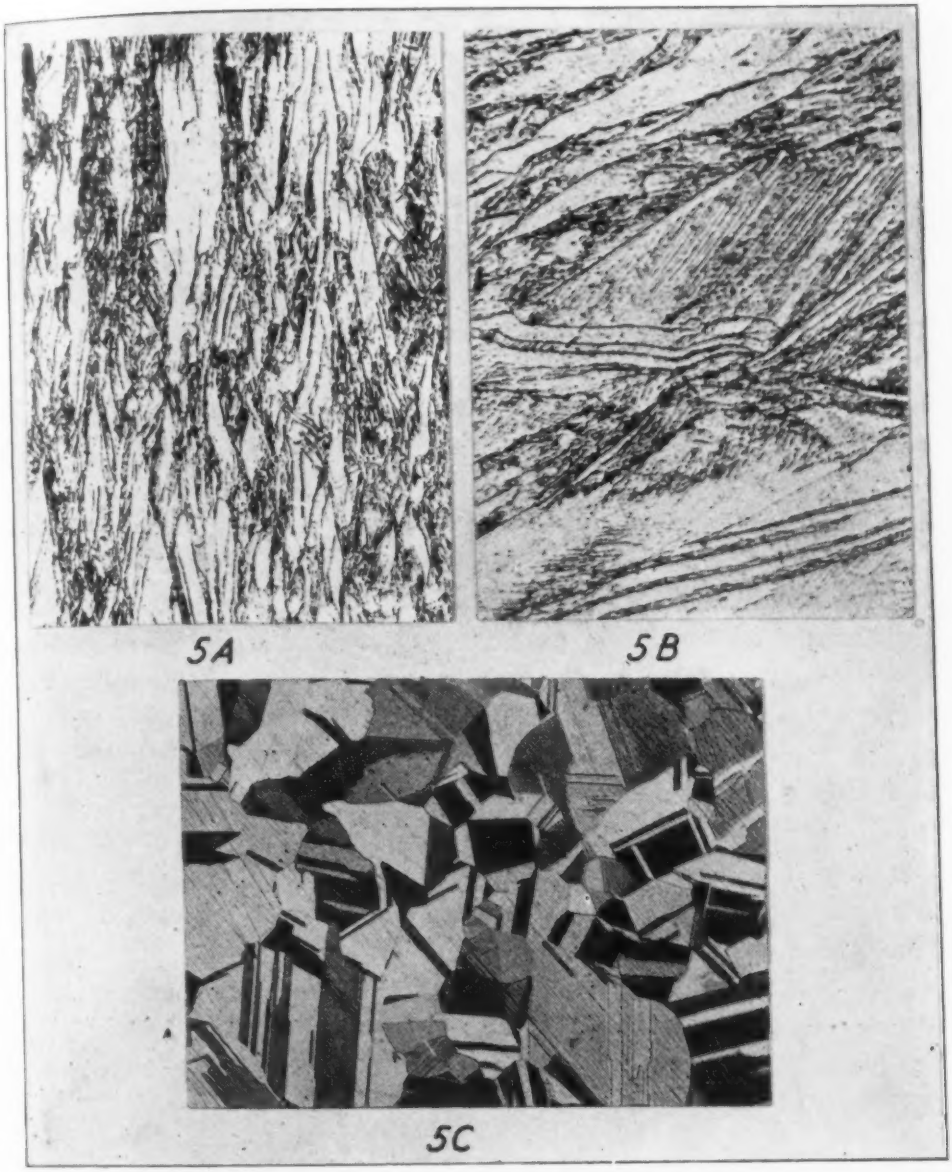


Fig. 5—(a) Alloy Al-7.0 per cent, Ni.-1.0 per cent, Rolled Cold 0.40 inch to 0.20 inch not Annealed, 100x.
(b) Same as (a) 500x.
(c) Alloy Al-7.0 per cent, Rolled Cold 0.40 inch to 0.20 inch Annealed at 1200 degrees Fahr. 100x.

resulting from high pouring temperature or slow cooling produced by other causes. This is also true of the harder alloys particularly those of the binary system containing about 10 per cent of aluminum; there is in this case, however, a rather general improvement in tensile properties. On the other hand, well-made alloys are heat treated as a regular practice in order to increase rigidity, strength

and hardness and special treatments are used to fit the material for bearing purposes. The tempering applied after quenching may be adjusted to produce partly decomposed beta, or the beta may be completely broken down to the eutectoid; at 100 diameters the latter generally is gray on an etched surface, whereas the former appears quite black; commercial heat treated castings frequently contain a mixture of the two structures. The use of appreciable amounts of added elements affects the microstructure profoundly, particularly subsequent to quenching or quenching and tempering.

Forging of alloys, particularly those of duplex structure also has its influence upon the microstructure, greatly altering grain size and form and in some cases completely changing the form and distribution of special constituents due to third elements in the alloy.

Some features of these commercial cast alloys are shown in Figs. 6 and 7. In Fig. 6 are reproduced structures of an aluminum-iron bronze as sand cast and as chill cast and then heat treated. The influence of the method of casting (i. e. the original micro-segregation of aluminum and perhaps iron) upon the distribution of alpha and beta solutions in the heat treated state, is striking. Manganese has a milder influence than iron in retarding structural alteration by heating, while the influence of nickel is great but of quite different character (see Fig. 7); the alloy containing manganese more nearly approaches in structural features the pure binary combinations.

In Fig. 8 some forged alloy structures are reproduced illustrating in one instance the effect of forging and heat treatment upon the form of the iron constituent and in the other the change in the fineness of "as quenched" beta due to change in composition.

II. Manufacture

(a) Founding Practice

Current methods in the melting and pouring of copper-base alloys containing much aluminum recognize several properties that are productive of serious losses when their effects are disregarded:

(a) High solidification shrinkage (about twice that of brass)

(b) Ease of formation of dross (Al_2O_3) by improper furnace practice or by agitation

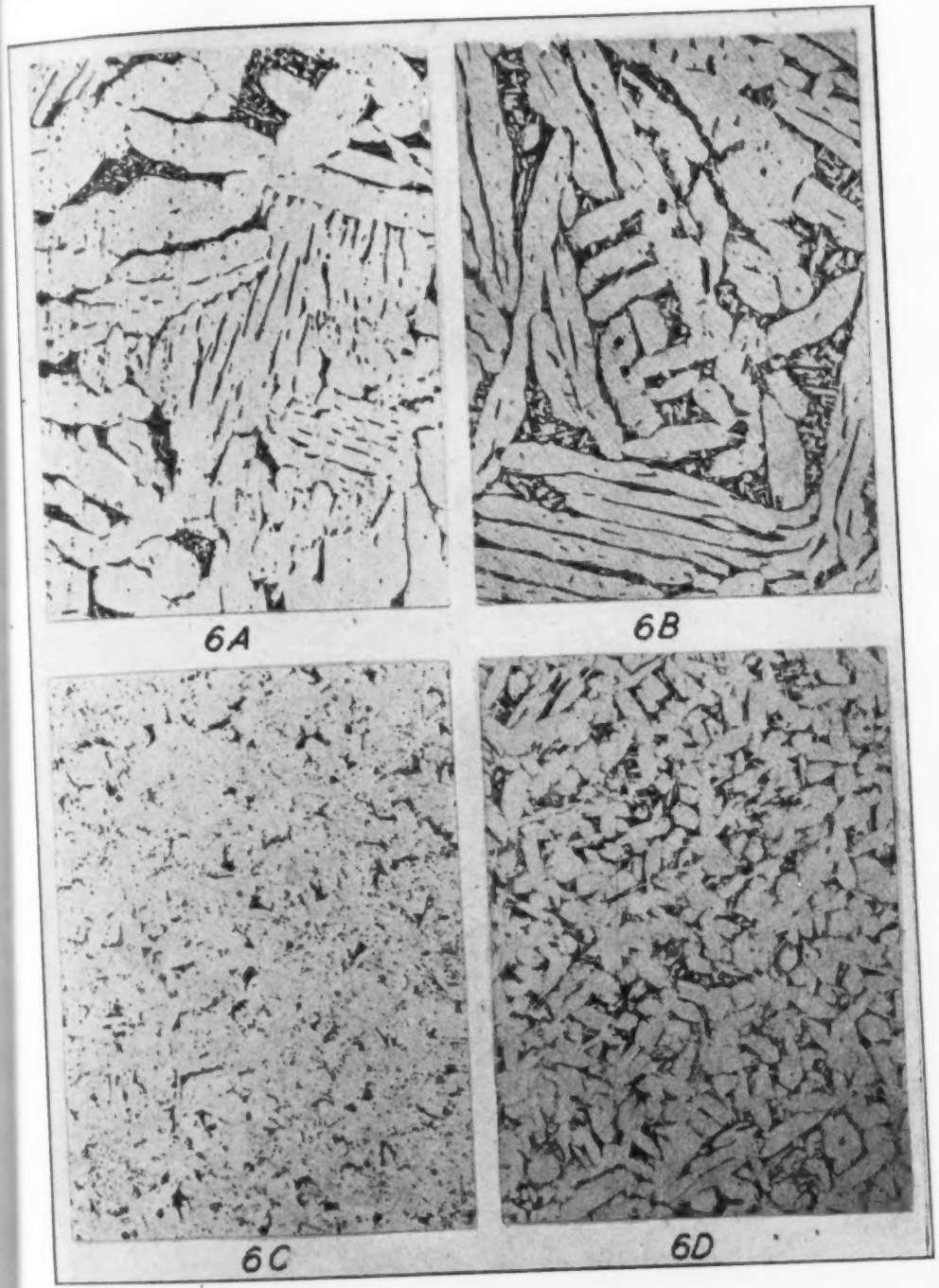


Fig. 6—(a) Alloy Al-8.31 per cent, Fe-2.44 per cent, As Sand Cast, 100x.
(b) Alloy Al.-8.31 per cent, Fe-2.44 per cent, Sand Cast, Heated to 1700 degrees Fahr., Water Quenched, Reheated to 850 degrees Fahr., Air Cooled, 100x.
(c) Alloy Al.-9.26 per cent, Fe-3.07 per cent, As Chill Cast, 100x.
(d) Alloy Al-9.26 per cent, Fe-3.07 per cent, Chill Cast, Heated to 1700 degrees Fahr., Water Quenched, Reheated to 850 degrees Fahr., and Air Cooled, 100x.

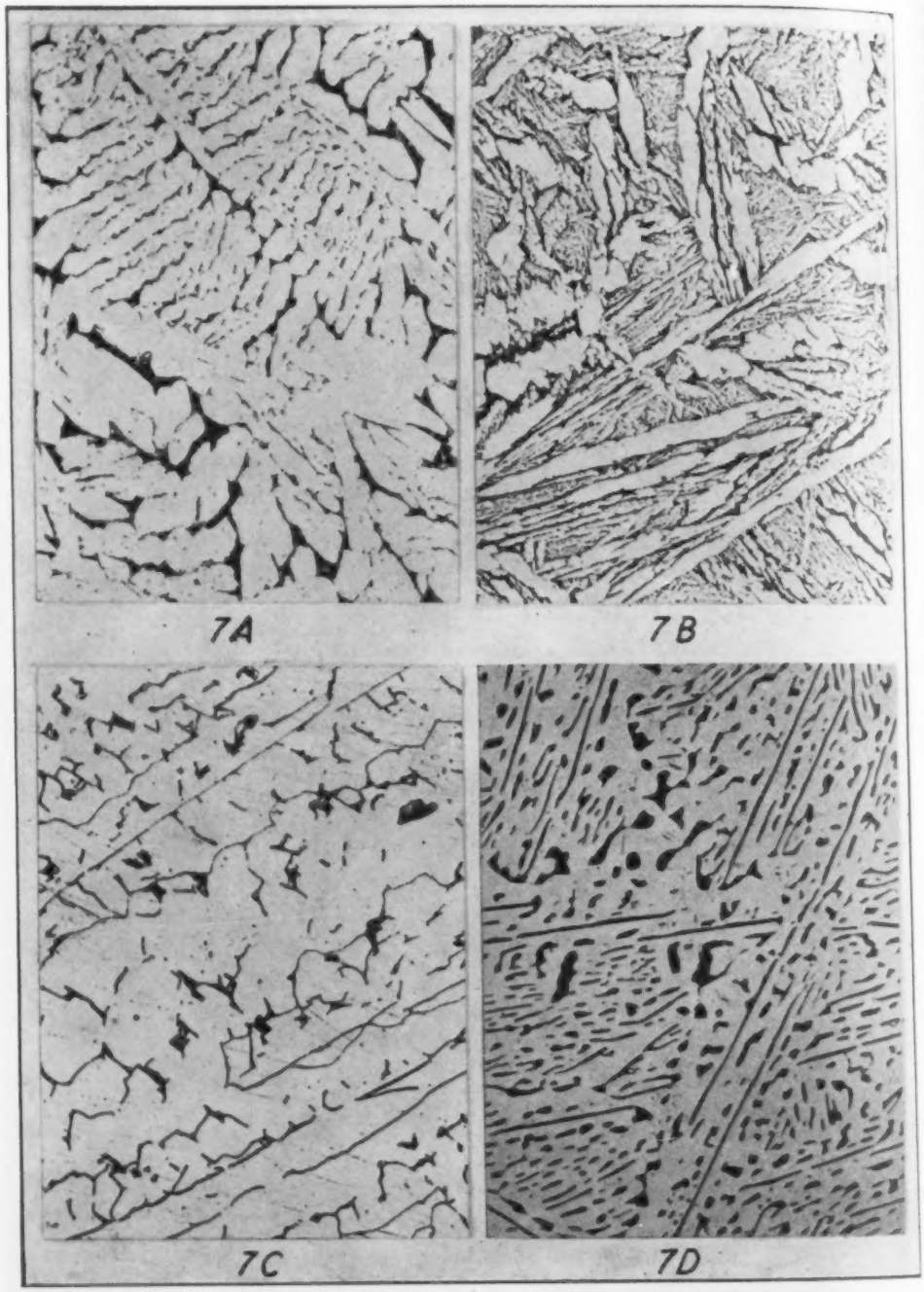


Fig. 7—(a) Alloy Al-9.16 per cent, Mn-1.74 per cent, As Chill Cast, 100x.
(b) Alloy Al-9.16 per cent, Mn-1.74 per cent, Chill Cast, Heated to 1700 degrees Fahr., Water Quenched, Reheated to 850 degrees Fahr., Air Cooled, 100x.
(c) Alloy Al-8.73 per cent, Ni-4.05 per cent, As Chill Cast, 100x.
(d) Alloy Al-8.73 per cent, Ni-4.05 per cent, Chill Cast, Heated to 1700 degrees Fahr., Water Quenched, Reheated to 850 degrees Fahr., Air Cooled, 100x.

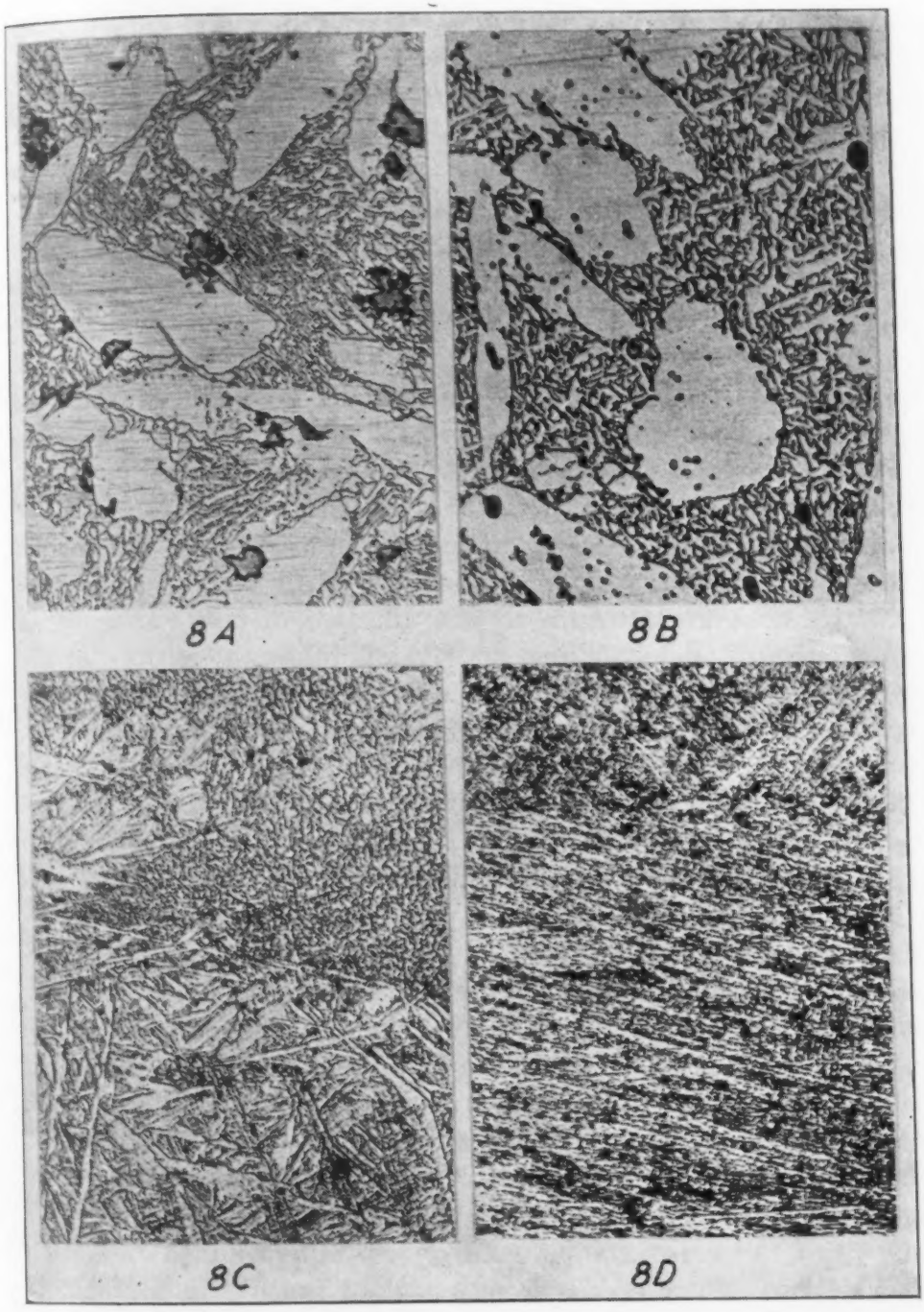


Fig. 8—(a) Alloy Al-8.55 per cent, Fe-2.95 per cent, Zn-9.53. As Sand Cast, Nodular Iron Constituent, 500x.

(b) Alloy Al-10.97 per cent, Fe-3.29 per cent, 1-inch Rd Forged heated to 1500 degrees Fahr. Furnace Cooled, Reheated to 940 degrees Fahr., (100 hrs.) Air Cooled, Rounded Iron Constituents, 500x.

(c) Alloy Al-10.24 per cent, Fe-0.28 per cent, 1-inch Rd Forged, Heated to 1650 degrees Fahr., Water Quenched, 500x.

(d) Alloy Al-10.97 per cent, Fe-3.29 per cent, 1-inch Rd. Forged, Heated to 1650 degrees Fahr. Water Quenched, 500x.

(c) Rapid evolution of large volumes of gas in the solidification range.

Practically all of the types of melting equipment common to the brass foundry have been used in the preparation of the aluminum bronzes and with suitable operation, metal of satisfactory character may be produced. Crucible furnaces of the pit-type are however generally preferred although electric furnaces (notably of the rocking types) have recently demonstrated highly creditable performance.

A satisfactory procedure is to first melt the copper under charcoal and then to deoxidize the melt by the addition 0.1 to 0.2 per cent of manganese. This operates to conserve the aluminum and, what is far more important, to reduce the necessity for deoxidation by the aluminum, with the simultaneous formation of large amounts of Al_2O_3 which is difficult to remove from the molten alloy. The oxide that does form in spite of all precautions may be removed to a great degree by the addition of small amounts of manganese sulphate, forcing the crystals below the surface of the bath and stirring with the least possible disturbance of the surface. The copper used should be electrolytic or equivalent quality, since such elements as arsenic and antimony seriously impair the properties of the alloys. Primary aluminum of the 98 or 99 per cent grades should be used; secondary or scrap aluminum of unknown origin is dangerous since it may contain large amounts of silicon which even in small proportions greatly reduces the ductility of aluminum bronze. For a similar reason phosphor-copper, the common deoxidizer of the brass and bronze founder, must not be used to replace the manganese. Magnesium may be used here or as a final addition but its excessive use is to be guarded against, as residual amounts may impair mechanical properties. Other elements to be added to any melt are best introduced at definite stages of the melting period. Nickel can be added as metal or as a 50:50 copper-nickel alloy after the copper is melted and prior to its deoxidation. Manganese is best added just after deoxidation. When adding iron, it is good practice to add half of the aluminum to the deoxidized melt, (the iron dissolves more readily after this addition), then all the iron slightly preheated, and then the balance of the aluminum. Metals of low melting point may be added in a similar manner except that only a small

proportion of the aluminum need be reserved for the final addition.

After skimming off the charcoal and the dross that has risen to the surface, the metal should be permitted to cool to the lowest temperature that will permit satisfactory filling of the molds; this aids in reducing shrinkage. In the production of castings the location of gates and risers and their size is important in yielding sound articles. It is also highly important that the entry of the metal into the mold be very quiet, free from ripples, surges, splashing and jet effects; such actions are productive of layers and masses of aluminum oxide that destroy the continuity of the metal. In small chill castings this oxide is finely divided, well disseminated and usually unobserved; in sand castings of moderately great section, it accumulates in masses usually near the surface and ruins both castings and cutting tools; in large chill castings such as ingots it coagulates also and generally reaches the mold walls or the pipe cavity.

As previously noted, the solidification interval in the binary copper-rich alloys is small, not over 18 degrees Fahr. (10 degrees Cent.) If melting and deoxidation have been indifferently practiced large amounts of gases given off during solidification will be entrapped due to this narrow range and appear as "worm-holes" quite similar in form to the trails of the destructive wood-borers. The narrow freezing interval is however an advantage in that it minimizes coring in the primary crystals (difference of composition from beginning to end of freezing). Also diffusion in the alloy is rapid and such coring as occurs, if not removed in cooling from the freezing temperature, is easily destroyed by subsequent heating for working or annealing or hardening. The addition of third elements generally widens the solidification range and affects the solubility of gases in the melt. Iron is particularly helpful although it, as well as other metals, further increases the normally high shrinkage. At the same time these elements increase coring and decrease diffusion rates so that Guillet (101) recorded in a high-nickel aluminum bronze that 10 hours at 1652 degrees Fahr. (900 degrees Cent.) did not produce complete homogeneity. It is perhaps worthy of note that increasing the aluminum content of the binary alloys increases the difficulty of securing sound castings particularly after this element reaches 11 per cent.

When the binary alloys with 8 to 11 per cent of aluminum

are cast in large sections and permitted to cool slowly as in a sand mold the grain size enlarges to the point where many grains seem to have merged into one; in addition the beta constituent breaks down completely into the alpha-delta eutectoid and the individual particles become quite coarse. The phenomenon has been erroneously termed "self-annealing" perhaps because of the similiarity of the results to those of reheating followed by very slow cooling. It is these results rather than the term that are of importance—low tensile strength and extremely low elongation—true brittleness and absence of normal resistance to impact stresses. This deterioration may be avoided by withdrawal of the cast form from the mold while quite hot and cooling in air or by water but as these alloys harden when rapidly cooled from above about 1022 degrees Fahr. (550 degrees Cent.) the cure may be almost as bad as the disease. Although a simple corrective is available in quenching and tempering by reheating after cooling in the mold, the simplest and most economical remedy is a change of composition. Iron in amounts over 3 per cent with adjustment of the aluminum content to meet the required mechanical properties, affords the desired cure. Tin also is effective and zinc either alone or with a small amount of iron partly so, (decreases grain size but not eutectoid divorce) but both adversely affect physical properties. Vickers (254) gives the following comparative data:

Copper %	89.0	85.5	88.0
Aluminum %	10.0	8.2	7.0
Iron %	1.0	2.0	3.0
Manganese %	...	...	2.0
Zinc %	...	4.3	...
Tens. Strength (lbs/sq. in.)	53100	68500	74000
Elongation % in 2 inches	8	24	42

Interesting evidence of the influence of iron is recorded in Figs. 9, 10 and 11. Fig. 9 is an etched cross-section of a 10-inch cylindrical ingot taken just below the pipe. This ingot was of 90 per cent copper and 10 per cent aluminum, poured in a preheated iron mold. Fig. 10 is a similar section of an ingot poured under as nearly identical conditions as could be obtained by pyrometric control, but from metal containing 87 per cent copper, 10 per cent aluminum and 3 per cent iron. By analysis the aluminum contents were practically identical; the effect of the iron in altering the proportion of the beta constituent would be slight—an effect equal to something less than 0.50 per cent added aluminum. The differ-

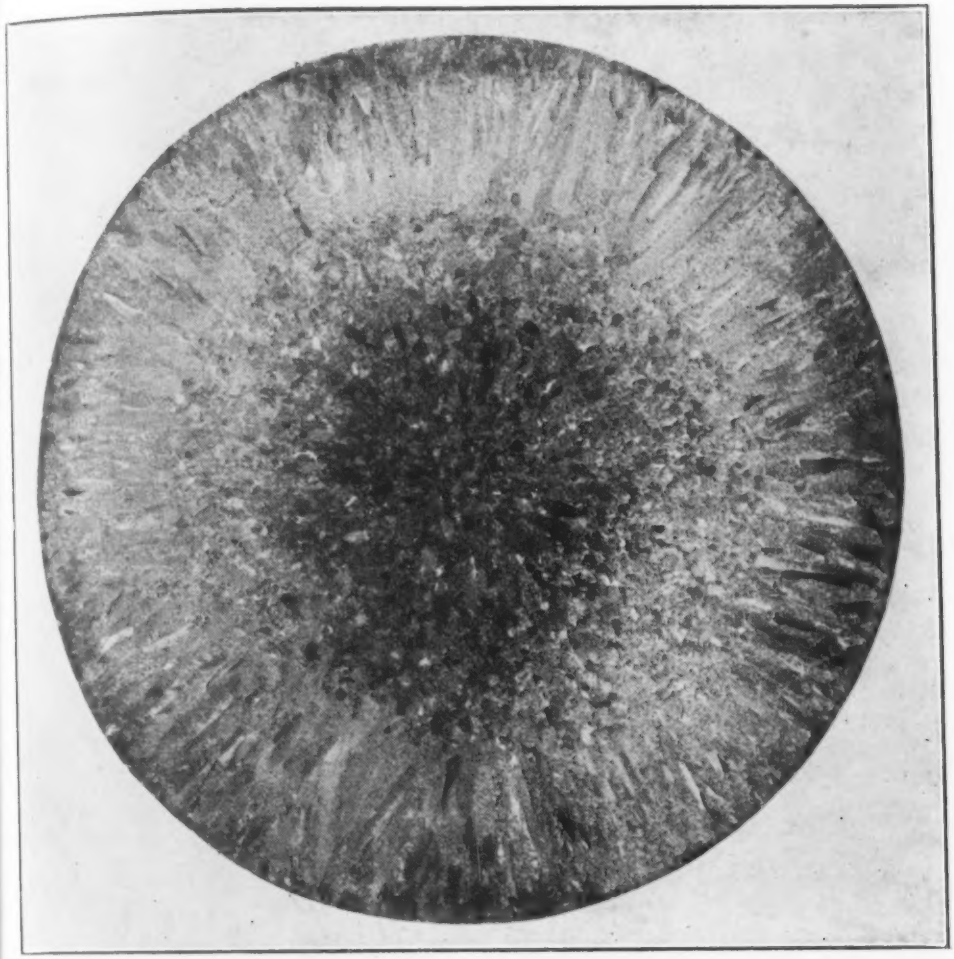


Fig. 9—Cross-Section of 10-inch Diameter Ingot Al-10.24 per cent, Fe-0.28 per cent, ¾ x.

ence in the growth of the surface dendrites and the size of the equiaxed crystals is striking. Fig. 11 is a comparison of microstructures prepared to show the effect of the iron upon the beta → alpha + delta transformation.

(b) Forging Practice

Due to the ease with which aluminum oxide is formed in these bronzes and its accumulation at the surface of the cast ingots, it is usually necessary to machine these ingots prior to forging. The amount of metal removed varies with the melting and pouring practice, the size of the ingot and the portion of its surface being cut; the usual limits are ⅛ and ⅝ inch. The need of this operation makes circular or square ingots most convenient. The develop-

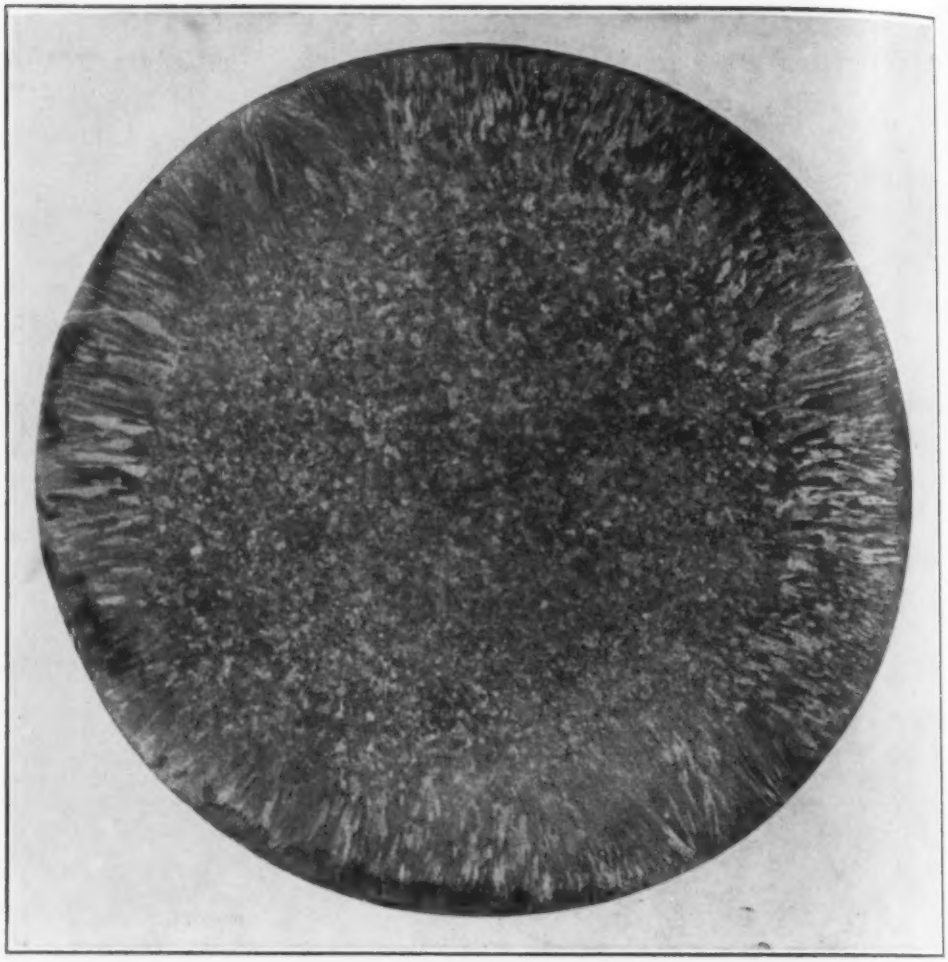


Fig. 10—Cross-Section of 10-inch Diameter Ingot Al-10.27 per cent, Fe-3.22 per cent, ¾ x.

ment of a process to remove troubles from oxides by the prevention of oxide formation during pouring, has been held by those interested in its use, to avoid the need for this machining of ingots. The process involves fastening the inverted mold to the melting pot just prior to pouring and rotating the assembled unit so as to permit rapid yet quiet transfer of the metal into the mold. The size of the ingot would appear to exert a great influence upon the feasibility of and the results obtained by such a method.

Due to the high thermal conductivity of the alloys and the fairly high forging temperature, heating is rapid and thermal gradients low. Hence, even with the brittle high-aluminum binary alloy ingots, heating for working is rapidly accomplished. A suit-

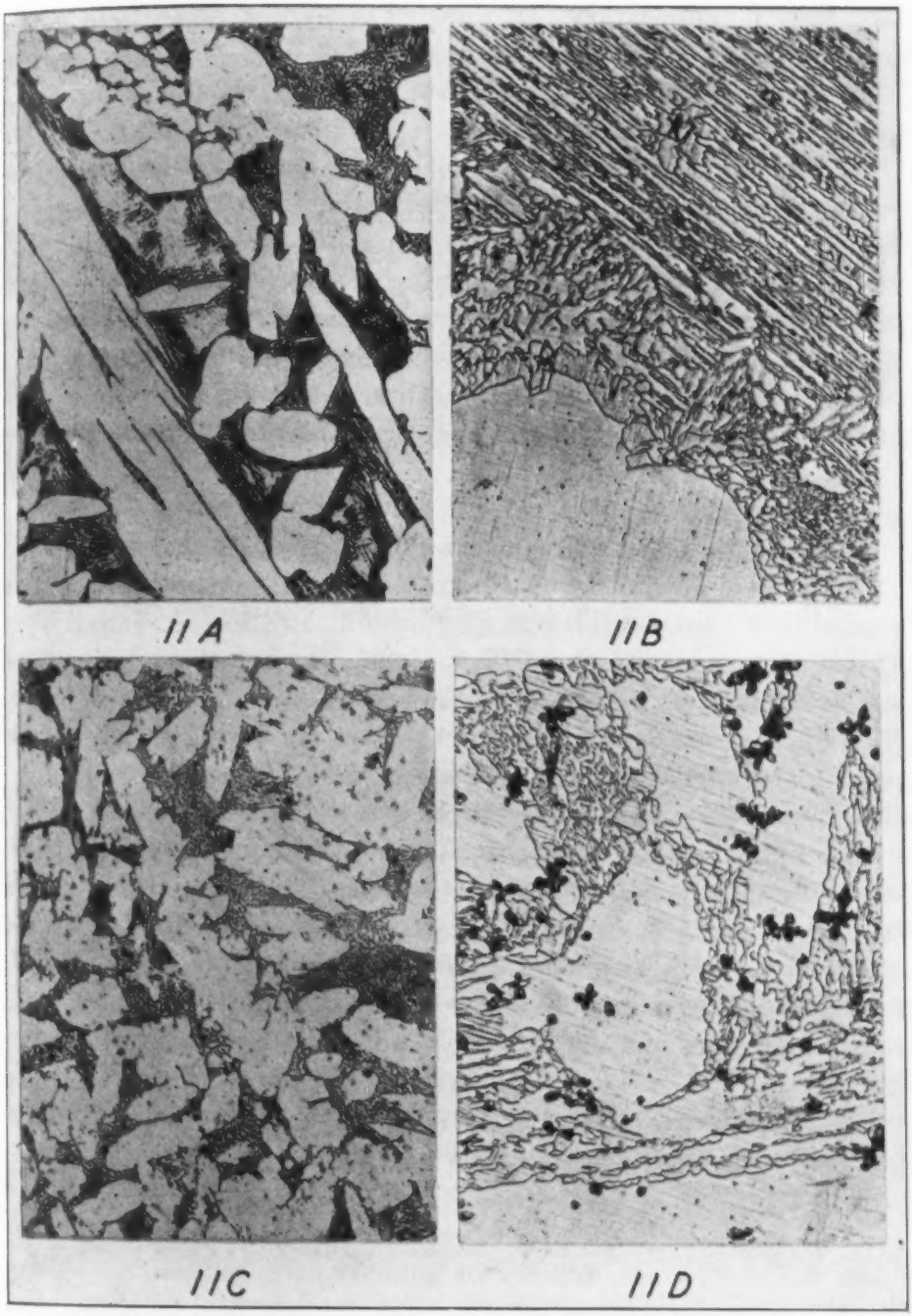


Fig. 11—(a) Center of 10-inch Ingot Al-10.24 per cent, Fe-0.28 per cent, 100x.
(b) Center of 10-inch Ingot Al-10.24 per cent, Fe-0.28, 500x.
(c) Center of 10-inch Ingot, Al-10.27 per cent, Fe-3.22, 100x.
(d) Center of 10-inch Ingot Al-10.27 per cent, Fe-3.22, 500x.

able initial temperature for forging is 1652 degrees Fahr. (900 degrees Cent.) The alloys are workable over the entire range from this to room temperature but if heavy reductions are contemplated, forging should be stopped at about 1346 degrees Fahr. (730 degrees Cent.) Due to the optical properties of the high-copper alloys the worker in steel will find them "looking hotter" than they really are; pyrometric control is therefore, initially at least, a sound investment for burning occurs easily and cold-working of heavy sections is productive of cracks that spread rapidly. Like many other nonferrous alloys, the aluminum bronzes frequently shear internally when hot-worked under conditions permitting too free flow. Consequently bars should be formed in V-dies rather than on flat dies and round bars finished from squares by swaging.

These alloys are quite resistant to oxidation at forging temperatures and do not "scale." On cooling after forging they are covered by a thin reddish film, part of which at least can be rubbed off without much effort. This property makes these bronzes of particular interest to the drop forger.

It is interesting that although the alloys of higher aluminum content are much stronger and more rigid when cold than those with lower aluminum percentages, these richer alloys are far softer at the forging temperature, more so than would be anticipated from the small difference in freezing temperature. They have all been successfully upset in bolt heading equipment, forged into rings on drop hammers, lever-hammers and forging machines, worked under presses on mandrels to form tubes by increasing both length and diameter and in short subjected to all steel-forging operations.

As previously noted the alloys may be cold-worked and by this process develop high strength although at the expense of some ductility.

Hot-rolled, cold-rolled and cold-drawn rods and cold-rolled sheets and strips are articles of commercial production. Alloys of 5 to 7 per cent aluminum with and without iron or manganese or nickel have been put through pressing and drawing operations using the same die equipment as employed for brass or for copper. It is well in such work to observe the effect of added elements upon recrystallization phenomena; iron markedly raises the re-

crystallization temperature which is obviously of importance in process annealing of cold-worked articles.

(c) Machining Practice

The aluminum bronzes machine quite differently from other nonferrous alloys. The alpha alloys and those with only a small proportion of beta (about up to 9 per cent aluminum with or without small additions of other elements) are strong and also extremely tough. With much beta or delta the alloys may or may not be strong but they are quite "hard." Either combination of properties is severe upon cutting tools and to these ordinary demands made upon them are added the abrasive action of any free Al_2O_3 present.

For most cutting the usual high rake angles of tools for nonferrous metal cutting, appear unsuitable. In fact, for severe rough turning operations lower rake angles than for steel have proven exceptionally effective. Chips obtained from such tools are of interesting form and are shown in Fig. 12. The forging cut contained 9 per cent aluminum and 3 per cent iron and its properties averaged 80,000 pounds per square inch tensile strength and 32 per cent elongation in 2 inches. Chips taken in cutting a coarse thread on this forging are shown in Fig. 13; the middle chip was produced in the first cut, the upper one in an intermediate heavy cut and the second one in a finishing cut. The fourth chip in this figure resulted when removing the forging surface and the last chip when taking a ¾-inch wide, 0.002-inch deep finishing cut on the surface of the cylinder with a broad-nose tool. These tools, including the threading tool, were the same as used for cutting nickel steel of about 100,000 pounds per square inch tensile strength. They were of high speed steel but were dulled (by abrasion, not heat) more rapidly than when cutting the steel.

(d) Miscellaneous Manufacturing Operations

With up to 5 per cent of aluminum, these bronzes generally offer no difficulties in soldering using ordinary lead-tin solders. With higher aluminum content, troubles arise due presumably to the persistent rapid formation of a film of aluminum oxide on the surface of the metal. It has been recorded (161) that an alloy of about 59 per cent zinc and 41 per cent cadmium is suit-

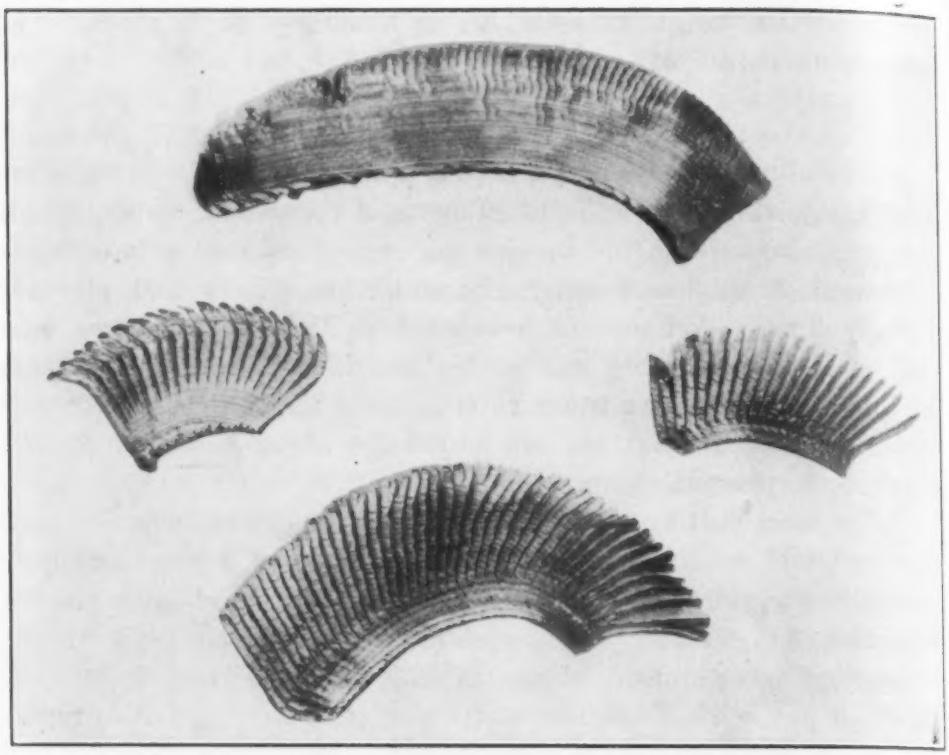


Fig. 12—Chips from Aluminum Bronze Forging Al-9.0 per cent, Fe-3.0 per cent, Roughing cut.

able for these higher aluminum bronzes but a more certain and probably more reliable method consists of coating the surfaces to be joined with a thin electrodeposit of copper and then using ordinary solders.

Brazing is satisfactorily carried out with the lower melting point spelter solders such as 52 per cent copper, 46 per cent zinc and 2 per cent tin. Welding has not been a general success but moderately good results have been obtained with a welding rod of aluminum bronze containing some manganese and using fluxes of similar composition to those found suitable in joining the aluminum-rich alloys.

Pickling to remove the thin oxide discoloration due to hot working may be satisfactorily performed by dilute sulphuric acid, preferably two to three times as strong as used for pickling steel. The natural golden yellow color may be brought out by short immersion in nitric-sulphuric acid mixtures or by the use of mixtures of sulphuric acid and saturated aqueous chromic acid. When such carefully cleaned surfaces are heated as high as 752 degrees Fahr.

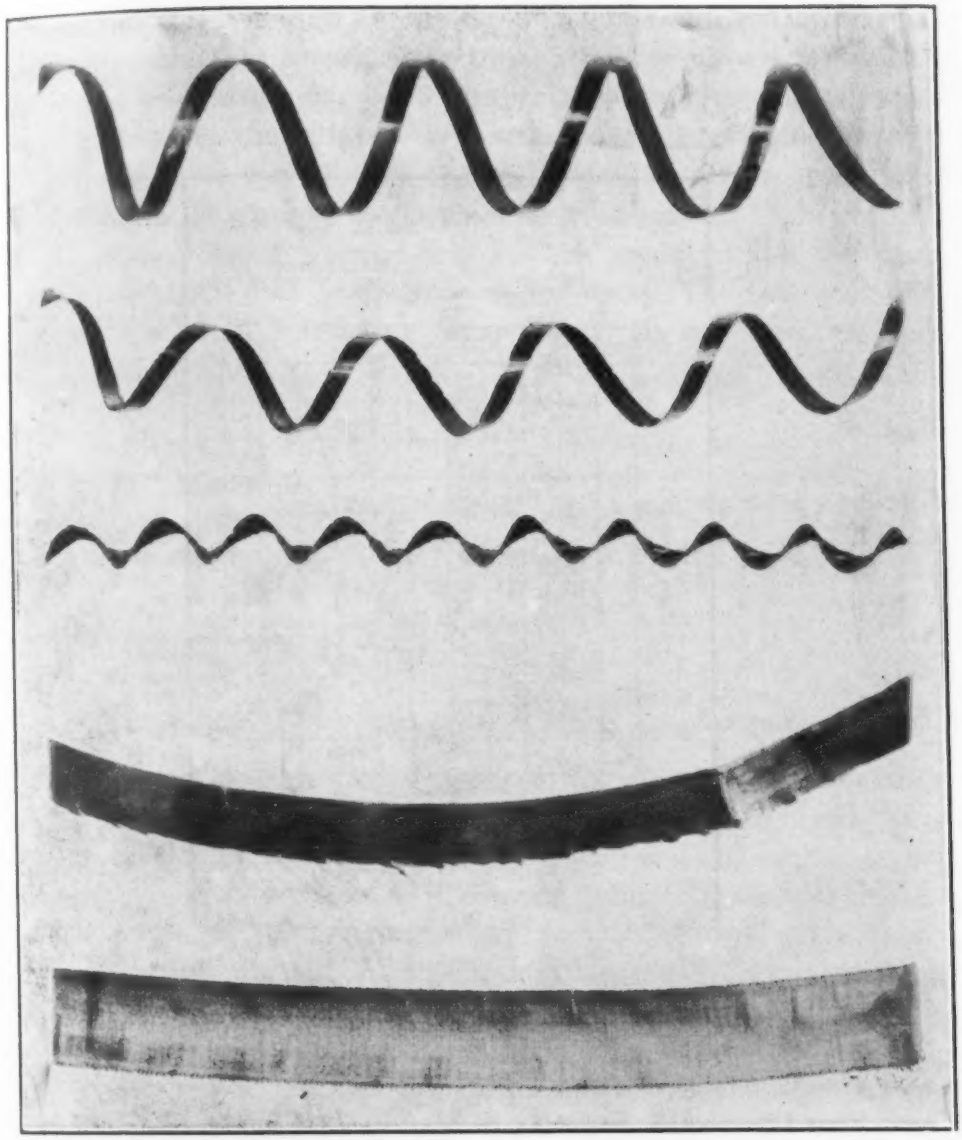


Fig. 13—Turnings from Threading, Rough Turning Forging Surface, and Broad-Nose Tool Finishing of Aluminum Bronze Forging Al-9.0 per cent, Fe-3.00 per cent.

(400 degrees Cent.) a uniform thin black shiny oxide film forms; this is tightly adherent and quite resistant to penetration by fluids.

III. Mechanical Properties

(a) The Binary Alloys

The greater portion of the test data recorded for these simple alloys has been drawn from the researches of Carpenter and Edwards (58). Although the molding practice employed by these

investigators was not conducive to the soundest cast test bars so that the tensile strength to a small degree and elongation to a greater degree are below values obtainable with these alloys, the deviations are not serious and their results may be studied to ad-

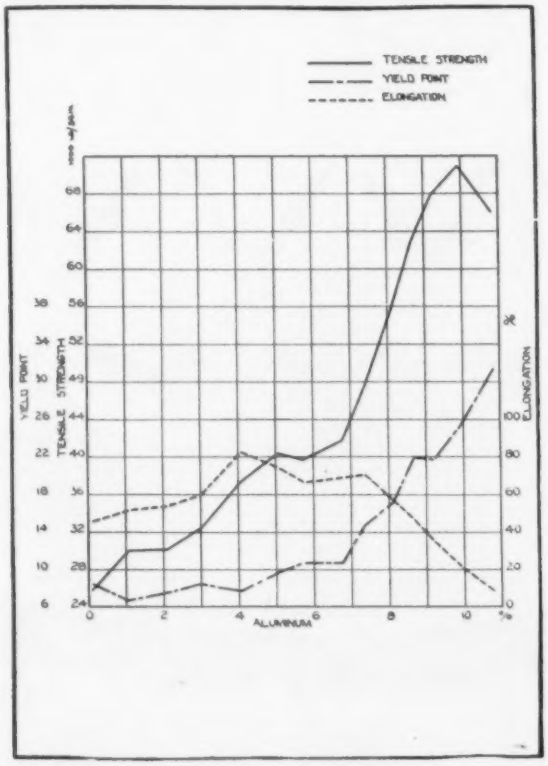


Fig. 14—Tensile Properties of Sand Cast Binary Aluminum Bronzes (Carpenter & Edwards.)

vantage. These comments do not, of course, apply to the ingots and the bars rolled from them.

Fig. 14 gives the tensile properties of sand castings containing up to 11 per cent aluminum. The interesting features are the high ductility accompanying good tensile strength (as well as remarkable constancy of properties) in alloys of 5 to 7 per cent aluminum, the rapid increase of strength properties above 7 per cent aluminum due to the appearance of the beta solid solution, and the tensile strength maximum (but not hardness) in the vicinity of 10 per cent aluminum. In the hot-rolled bars (Fig. 15) practically the same condition is observed. The combination for 9.4 per cent aluminum of over 83,000 pounds per square inch tensile strength with 40 per cent elongation is worthy of note. As a result

of cold drawing (Fig. 16) the properties of the higher aluminum alloys are very greatly enhanced. Again the constancy of properties between 5 and 7 per cent is observed. The author has checked some of these results in his own work as recorded in Table I.

It should be noted that the yield point of Carpenter and Edwards was determined by dividers whereas values of this property in Table I are the unit stresses that produced 0.5 per cent elongation of the test bars while under load. The fact that the beta solid solution was harder than the alpha solution and that

Table I
Tensile Properties of Low-Aluminum Binary Alloys

Aluminum Per Cent	State	Prop. Limit lbs./sq. in	Yield Pt. lbs./sq. in.	Tens. Str. lbs./sq. in.	Elong. % in 2"	Reduction Area %
3.96	Cast and Annealed	6100	8,700	34,700	83.5	80.3
5.25	Cast and Annealed	6940	11,300	41,000	79.4	80.4
6.22	Cast and Annealed	6600	9,900	43,000	86.8	72.0
7.23	Cast and Annealed	8000	11,700	41,800	86.0	60.3
3.96	Forged and Annealed	8200	12,500	47,000	81.3	80.5
5.25	Forged and Annealed	7700	12,300	50,600	77.0	70.2
6.22	Forged and Annealed	8700	12,500	52,900	74.5	68.6
7.23	Forged and Annealed	9200	14,300	54,100	95.5	70.6

hardening by heat treatment was possible through the retention of the former at room temperature, has already been mentioned. Fig. 17 illustrates the change in tensile properties of sand castings upon water quenching from 1472 degrees Fahr. (800 degrees Cent.). It will be noted that no hardening results below about 8.3 per cent of aluminum. Such changes as may appear in lower-aluminum binary alloys (beta is possible above 7.5 per cent aluminum) is seldom of a magnitude greater than the differences between companion bars. With 10 per cent aluminum the increase in tensile strength is of the order of 60 per cent and the decrease in elongation about 90 per cent. The changes produced in the hot-worked alloy by similar treatment are not quite as great; details appear in Table II.

This table shows also the small differences in tensile properties in the cast and rolled bars of the higher aluminum alloys; in alloys of intermediate aluminum content (4 to 7.5 per cent) this condition does not obtain. Records in a later section of the paper will add interesting confirmation of this fact. The similarity is no doubt associated with the marked comparability of the microstructures of the cast and of the hot-worked alpha plus beta compositions.

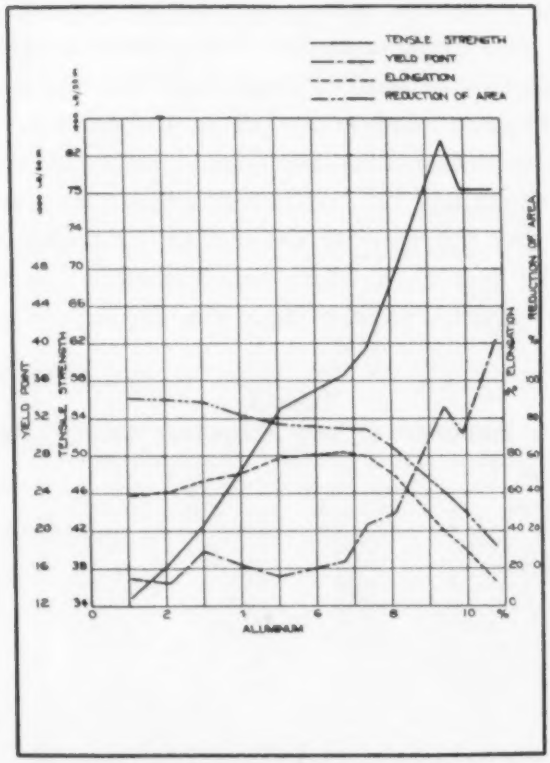


Fig. 15—Tensile Properties of 1-¼-inch Hot-Rolled Bars of Binary Aluminum Bronzes (Carpenter & Edwards.)

Table II

Range of Tensile Properties—Typical Alpha and Alpha + Beta Binary Alloys

Aluminum Per Cent	Condition of Specimen	Yield Point lbs./sq. in.	Tens. Str. lbs./sq. in.	Elongation % in 2″	Reduction Area %
7.35	Sand Cast	14,800	47,700	71.0	...
7.35	Sand Cast 800° C. Slowly cooled	13,200	45,000	81.0	...
7.35	Sand Cast 800° C. Water quenched	15,000	44,800	80.0	...
7.35	Chill Cast	.....	48,400	84.0	...
7.35	Chill Cast 800° C. Slowly cooled	13,400	45,200	80.0	...
7.35	Chill Cast 800° C. Water quenched	16,400	44,400	79.0	...
7.35	Rolled Bar 1¼″ dia.	20,800	61,400	80.0	75.3
7.35	Rolled Bar $\frac{13}{16}$″ dia.	23,800	66,500	72.5	74.3
7.35	Rolled Bar $\frac{13}{16}$″ dia. 800° C. Slowly cooled	16,600	56,900	80.5	74.3
7.35	Rolled Bar $\frac{13}{16}$″ dia. 800° C. Water quenched	17,900	57,100	82.0	74.8
7.35	Cold Drawn Bar $\frac{13}{16}$″ dia.	55,100	70,400	48.0	58.8
9.90	Sand Cast	25,300	71,000	21.7	...
9.90	Sand Cast 800° C. Slowly cooled	29,800	Broke in shoulder	...	...
9.90	Sand Cast 800° C. Water quenched	50,200	112,100	3.0	...
9.90	Chill Cast	27,800	82,700	30.5	...
9.90	Chill Cast 800° C. Slowly cooled	37,000	59,100	5.0	...
9.90	Chill Cast 800° C. Water quenched	39,600	86,300	22.0	...
9.90	Rolled Bar 1¼″ dia.	30,400	78,400	31.5	30.5
9.90	Rolled Bar $\frac{13}{16}$″ dia.	33,100	85,300	28.8	30.8
9.90	Rolled Bar $\frac{13}{16}$″ dia. 800° C. Slowly cooled	35,200	63,800	6.5	10.2
9.90	Rolled Bar $\frac{13}{16}$″ dia. 800° C. Water quenched	58,600	101,800	11.0	16.8
9.90	Cold Drawn Bar $\frac{13}{16}$″ dia.	90,500	98,500	13.0	22.2

Table III

Effect of Low-Temperature Heating on Tensile Properties of Aluminum Bronze (1-inch Forged Rounds as Treated)

COMPOSITION Al.	Fe	Cu	HEAT TREATMENT (Degrees F.)	Prop. Limit lbs./sq. in.	Tens. Str. lbs./sq. in.	Elong. % in 2"	Reduc. Area %	Izod ft.-lbs. (a)	Brin. (c)	HARDNESS Rock. (b)	Scler.
10.24	0.28	89.50	1500 (15m.) fce cool	12,700	69,300	11.5	16.8	6.0	131	—1.5	27.4
10.24	0.28	89.50	1500 (15m.) fce cool 940 (100-hr.) air cool	16,000	61,500	7.7	9.6	7.5	126	—5.5	25.4
10.24	0.28	89.50	1650 (15m.) Water	16,400	114,900	1.3	3.6	8.6	243	30.9	57.8
10.24	0.28	89.50	1600 (15m.) Water 940 (100-hr.) air cool	29,200	87,500	15.0	19.9	14.5	143	5.3	26.6
10.24	0.28	89.50	1650 (15m.) Water 1000 (1-hr.) air cool	30,700	80,800	9.0	15.1	16.9	145	6.8	31.9
10.97	3.29	85.75	1500 (15m.) fce cool	17,800	73,600(d)	1.3	1.2	3.0	179	13.0	30.4
10.97	3.29	85.75	1500 (15m.) fce cool 940 (100-hr.) air cool	29,200	86,200	3.8	5.1	2.5	179	13.8	30.4
10.97	3.29	85.75	1650 (15m.) Water	14,100	78,900	1.3	2.0	6.4	237	30.8	60.0
10.97	3.29	85.75	1600 (15m.) Water 940 (100-hr.) air cool	45,100	95,500	2.3	3.6	5.0	217	21.8	35.6
10.97	3.29	85.75	1650 (15m.) Water 1000 (1-hr.) air cool	40,800	95,600	2.5	6.2	3.8	216	23.0	40.1

(a) Mesnager notch, 2 mm. dia., 2 mm. deep.
(b) 150 kg., diamond cone, C scale.
(c) 3000 kg., 30 sec.
(d) Broke in thread.

A further observation is that annealing softens the alpha alloys without appreciable change in ductility; the alpha plus beta alloys on the other hand develop upon annealing not only a lower strength but a greatly decreased elongation as well. Carpenter and Edwards state that any temperature above 752 degrees Fahr. (400 degrees Cent.) produces this condition but the author's data in Table III indicate that this is true only for previously annealed or slowly cooled material; quenched articles are not adversely affected even after 100 hours at 940 degrees Fahr. (505 degrees Cent.). Also the introduction of iron will be observed to have diminished the ill effects of low-temperature treatment and made the changes in ductility from these treatments only such as would be expected to accompany the hardness changes.

With alloys containing 9 per cent or less of aluminum, variation of the quenching temperature between 1112 and 1652 degrees Fahr. (600 and 900 degrees Cent.) does not greatly influence the increase in strength due to this treatment, although marked decrease in cooling rate by increase in section will reduce it to zero. With 9 to 11 per cent aluminum, the effect of quenching temperature is marked as noted in Table IV.

In studying the effect of tempering after quenching at different temperatures Grard (226) found a rehardening (previously mentioned by Portevin and Arnou) in the form of increased tensile strength occurring at about 572 degrees Fahr. (300 degrees Cent.); it was more pronounced when quenching from 1292 degrees Fahr. (700 degrees Cent.) than from 1472 degrees Fahr. (800 degrees Cent.) or 1652 degrees Fahr. (900 degrees Cent.). The peak with the lower quenching temperature did not, however, represent higher strength than the peaks of the curves for higher quenching temperatures. With the lowest quenching temperature, a minimum elongation also occurred at 752 degrees Fahr. (300 degrees Cent.) but not the minimum impact strength; with the 1472 degrees Fahr. (800 degrees Cent.) quench both minima were at a higher temperature while with the highest quenching temperature this was repeated for the impact resistance but no elongation minimum occurred, the curve being smooth from the lowest to the highest tempering temperatures.

Carpenter and Edwards' (58) Brinell hardness values in Table V show that the decrease in strength above about 10 per

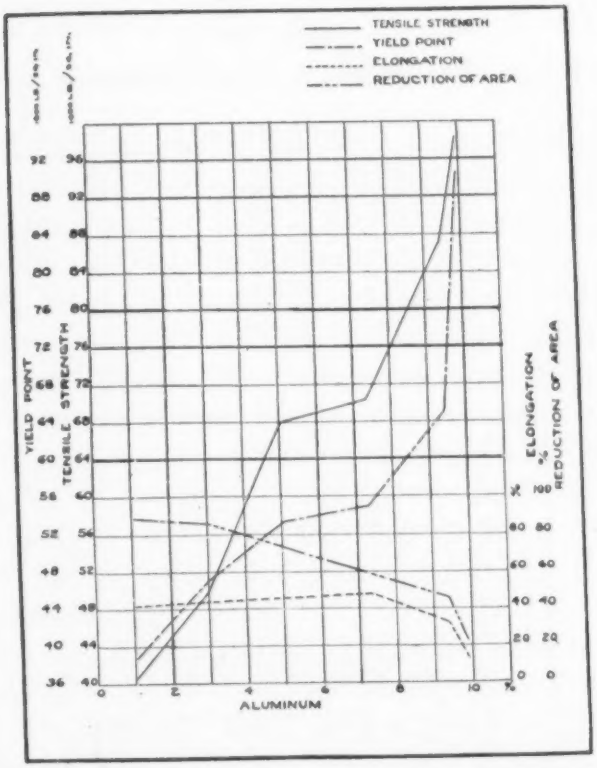


Fig. 16—Tensile Properties of $\frac{13}{16}$-inch Cold-Drawn Bars ($\frac{1}{16}$-inch Final Reduction after Annealing) of Binary Aluminum Bronzes (Carpenter & Edwards.)

Table IV

Influence of Quenching Temperature on Small Sections of Rolled 9.90 Per Cent Aluminum Binary Alloy

Quenching Temperature °C.	°F.	Yield Point lbs./sq. in.	Tensile Strength lbs./sq. in.	Elongation % in 2"	Reduction Area %
600	1112	38,100	85,500	22.2	30.0
700	1292	40,500	89,200	15.4	20.6
800	1472	72,500	97,800	7.0	14.3
900	1652	89,200	115,300	3.0	4.8

Table V

Brinell Hardness of Binary Copper-Aluminum Alloys

Aluminum (Per Cent)	Hardness
0.10	47
2.99	75
5.07	92
7.35	98
9.90	154
11.73	197

Table VI

Torsion Tests of Binary Copper-Aluminum Alloys

Aluminum (Per Cent)	Maximum Stress lbs./sq. in.	Angle of Twist per in. of length at rupture (degrees)
0	37,400	912
0.10	47,900	1728
1.06	49,200	1448
2.10	51,500	1286
4.05	58,900	772
6.73	69,200	541
7.35	70,500	458
9.90	70,000	78
11.73	75,000	17

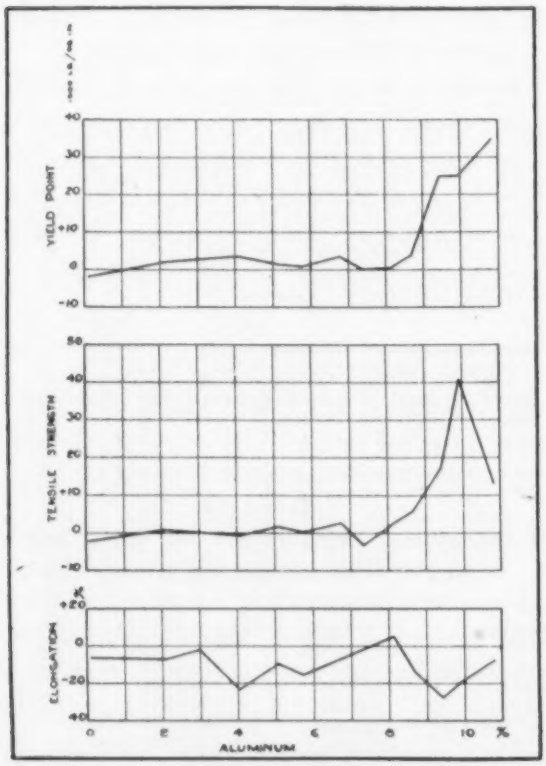


Fig. 17—Effect of Quenching from 800 degrees Cent. (1472 degrees Fahr.) on the Tensile Properties of Binary Aluminum Bronzes (Carpenter & Edwards.)

cent aluminum is the result of embrittlement due to absence of sufficient ductile alpha, for hardness continues to rise as the aluminum is increased beyond this amount. Values of torsional strength and ductility are given in Table VI. Reliable data on endurance properties are not numerous but a few tests from the work of McAdam (294) and Moore (271) are reported in Table VII.

There are also included a few data on compression and shear strength, the latter obtained not by torsion but by direct double shear.

The modulus of elasticity has been found by the author to vary with thermal and mechanical history from about 12 to about 19×10^6 pounds per square inch. Elastic properties are subject to many vagaries particularly in materials likely to contain great internal stress,—such as results from high temperature quenching. The stress-strain curve often shows no proportionality and yet release measurements give evidence of an elastic limit. In other bars, as in some rolled steels, the stress-strain diagram near the origin is composed of two straight lines and then curves slowly and smoothly up to the point of maximum strength; the second straight segment of the graph corresponds to a lower elastic modulus than does the first proportional segment. These studies are still incomplete.

Bregowsky and Spring (264) have determined the properties of alloys containing 5 per cent and 10 per cent of aluminum at elevated temperatures and their data appears in Fig. 18. The important features are the retention of room temperature strength to about 437 degrees Fahr. (225 degrees Cent.) and the failure of the alloys to lose further amounts of strength within the range of 752 degrees Fahr. (400 degrees Cent.) to 950 degrees Fahr. (510 Cent.).

(To be Continued in August TRANSACTIONS*)*

Educational Section

These Articles Have Been Selected Primarily For Their Educational And Informational Character As Distinguished From Reports Of Investigations And Research

FACTS AND PRINCIPLES CONCERNING STEEL AND HEAT TREATMENT—Part XIII*

By H. B. Knowlton

Abstract

This article discusses the effects of manganese in simple steels and the composition, properties and uses of various types of manganese alloy steels. Some new charts showing the physical properties of some of the pearlitic manganese steels are presented. The properties of the high manganese steels are described. The effects of manganese in steel castings and the properties of steels containing manganese in combination with other alloying elements are discussed.

Manganese in Plain Carbon and Alloy Steels

ALL varieties of steel contain, in addition to iron and carbon, certain other elements such as manganese, sulphur, phosphorus and silicon. The sulphur and the phosphorus are accidental impurities which tend to cause brittleness. Consequently in most forms of steel the content of these objectionable elements is kept as low as practicable. In some kinds of steel silicon is intentionally added while in others its presence is due to the fact that the silicon was not entirely removed during the refining of pig iron, (which always contains silicon,) into steel. Steels made by the basic processes usually contain less than 0.20 per cent silicon, while the acid-made steels contain about 0.30 per cent.

The presence of manganese, in all forms of steel, however, may be classed as intentional and beneficial rather than accidental

*This is the thirteenth installment of this series of articles by H. B. Knowlton. The several installments which have already appeared in Transactions are as follows: March, June and October, 1925; January, April, May, June, August, October and December, 1926; March and May, 1927.

The author, H. B. Knowlton, member of the Fort Wayne Group of the Society, is metallurgist of the Fort Wayne Works, International Harvester Company, Fort Wayne, Ind.

and injurious. The manganese content in most of the tool steels is between 0.15 and 0.30 per cent. The low and medium carbon steels, both plain carbon and alloy, usually contain 0.30-0.80 per cent manganese. Steels are not classified as alloy steels on account of the manganese content unless the proportion of manganese in the steel is intentionally raised above the figures just given, for some particular purpose. Thus a low carbon steel containing 0.90 per cent manganese would not be considered as a manganese alloy steel, while a tool steel containing the same amount of manganese might be classified as such. In the former case the manganese content is not greatly above the usual limits for low carbon steel, and consequently the properties of the steel will not differ greatly from those of ordinary steel. In the case of the tool steel containing 0.90 per cent manganese instead of 0.30 per cent, the properties are materially changed. Such a steel could probably be hardened by quenching in oil instead of water.

Functions of Manganese in Ordinary Steels

The functions of manganese in ordinary steels (i. e. all steels except the special manganese alloy steels), will be discussed first. These may be divided into two classes:—the function of manganese in purifying the steel during manufacture:—and the functions of the manganese left in the finished steel.

In some of the steel-making methods, manganese in the form of ferromanganese or spiegel (which may be described as cast irons high in manganese is intentionally added to the melted metal for the purpose of aiding in the purification. The manganese reduces the iron oxides in the melted bath to metallic iron and itself becomes oxidized and floats up to the top in the form of slag. In this way it aids in the production of a clean steel.

It may be worth noting in passing that some of the early attempts to make low carbon steel by the pneumatic method (commonly called Bessemer method) were not entirely successful if success be judged by modern standards. About this time Mushet found that the addition of manganese after the "blow" would deoxidize the metal and make sound steel. The later success of the Bessemer (or Bessemer-Mushet-Kelly) process depended quite largely upon the use of manganese.

It might seem possible to add only enough ferromanganese or spiegel to perform the cleansing action and produce a steel con-

taining practically no manganese. However, this is not practicable. In order to clean the steel thoroughly it is necessary to add an excess of the manganese alloy. Consequently there is always some manganese left in the finished steel.

The manganese which is left in the finished steel has several important effects. If the manganese content is sufficiently greater that the sulphur content, the manganese will combine with all of the sulphur to form manganese sulphide. If it were not for the presence of the manganese the sulphur would combine with the iron to form iron sulphide. While some claim that neither of these compounds is particularly desirable in steel, the iron sulphide is far more objectionable than the manganese sulphide, for when the sulphur is present in the form of iron sulphide, the steel is "hot-short"; in other words it is brittle during forging. Some writers claim that sulphur in the form of manganese sulphide is entirely harmless unless the sulphur content exceeds 0.10 per cent. This may be open to dispute. Most specifications written by users call for sulphur below 0.05 or 0.04 per cent even when the manganese is sufficiently high to combine with all of the sulphur.

The presence of manganese in steel is of further importance because it combines with carbon and dissolves in iron. In general it may be stated that manganese even in small quantities tends to increase the strength and the hardening power of steel and lower the toughness. It also lowers the critical point. The following data given by H. H. Campbell[1] and Camp and Francis[2] show the effects of manganese upon untreated steel.

"Each increase of 0.01 per cent manganese above 0.30-0.40 per cent raises the tensile strength in:

Carbon content	Basic O. H. Mn. above 0.30 per cent	Acid O. H. Mn. above 0.40 per cent
0.05	110 pounds	...
0.10	130 pounds	80 pounds
0.25	190 pounds	200 pounds
0.40	250 pounds	320 pounds

These figures will apply when the manganese is within the usual limits. It may readily be seen that even commercial variations in the manganese content of ordinary steels may have an effect upon the properties of the steel. For example the S. A. E.

[1]Manufacture and Properties of Iron and Steel: H. H. Campbell.

[2]Making, Shaping and Treating of Steel: Camp and Francis.

Specification for 1040 steel allows a variation of 0.30 per cent manganese and 0.10 per cent carbon. According to the above figure, 0.30 per cent variation in the manganese will make a difference of 7500 pounds per square inch in the tensile strength. A variation of 0.10 per cent in the carbon content produces a difference of about 9000 pounds per square inch in the tensile strength.

The above data applies to steel in the untreated condition. Manganese also has an effect upon heat treatment. Each 0.10 per cent manganese lowers the critical point on heating about 5 degrees Fahrenheit. In general, manganese increases the hardening power of steel. If the manganese and carbon contents are high enough the steel may be hardened by quenching in oil instead of water. In plain carbon tool steels which are to be quenched in water the manganese content is usually held below 0.30 per cent as there might be danger of cracking or brittleness with higher manganese. On the other hand, oil hardening tool steels may contain 1.25 or even 1.5 per cent manganese. The S. A. E. specifications for medium carbon steels call for manganese between 0.50 and 0.80 per cent. Case hardening steels according to the S. A. E. Specifications should contain 0.30-0.60 per cent manganese. Nevertheless, higher manganese steels have been used for case hardening with very good results. Such steels however should not be given the same heat treatment as those containing very low manganese. This will be discussed more fully later.

In general it may be said that manganese is one of the important elements in all forms of steel. Frequently it receives little attention, probably because it is so common. The presence of 0.30-0.80 per cent of manganese does not cause a steel to be classed as a "special" or an alloy steel. On the other hand if a steel were made with practically no manganese it would probably be classed as a "special" steel. One of the principal differences between ingot iron and the very low carbon steels is the very low manganese content of ingot iron.

Manganese as a Special Alloying Element

As already stated the effects of manganese in ordinary steels is worthy of study. Of even more interest is the effect of that element in the steels containing enough manganese to be classed as special manganese alloy steels. These steels may be best discussed

by dividing them into four classes depending upon the structure produced by slow cooling from above the upper critical point.

Guillet's diagram shown in Fig. 1 gives the normal structures of steels containing varying amounts of carbon and manganese. These are the structures which are produced by slow cooling from above the upper critical point. It will be noted that for steels containing less than 1.6 per cent carbon, the diagram is divided into three zones or areas. All of the the steels in the upper zone are

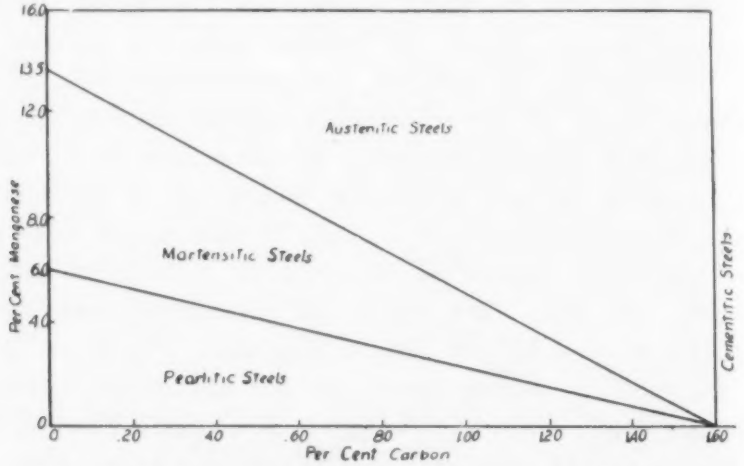


Fig. 1—Constitutional Diagram for Manganese Steel (After Guillet).

austenitic after slow cooling, while the steels in the middle zone have a martensitic structure and the steels in the lower zone a pearlitic structure after slow cooling. It will also be noted that the boundary lines of these zones depend upon the content of both carbon and manganese. Thus a carbonless iron containing less than 6.0 per cent manganese is pearlitic; steels containing zero carbon and 6-13.5 per cent manganese are normally martensitic; and steels with no carbon and over 13.5 per cent manganese are austenitic. Similarly steels containing 1.0 per cent carbon are normally pearlitic when the manganese is below 2.5 per cent, martensitic when the manganese content is between 2.5 and 7 per cent and austenitic when the manganese is above 7 per cent. Also, according to the diagram, steels containing over 1.6 per cent carbon are normally cementitic regardless of the manganese content. At present at least, the cementitic manganese steels seem to be of technical rather than of commercial importance. Consequently they will not be discussed herein.

Austenitic Manganese Steels

The high manganese steels containing 10.00-15.00 per cent of manganese and 1.00-1.50 per cent of carbon have important commercial uses. The common composition is about 12.00-13.00 per cent manganese and about 1.00 per cent of carbon or slightly over. The structure of such steels in either the quenched or slowly cooled condition is composed largely of austenite. When these steels are allowed to cool slowly from the casting temperature, considerable cementite separates out of the austenite or solid solution. Consequently the structure of cast manganese steel as observed through the microscope is composed of austentite crystals surrounded by a net work of cementite. This cementite is composed of carbides of iron and manganese and is extremely hard and brittle. As might be expected, a steel having this type of structure is comparatively weak and brittle. The tensile strength may be as high as 100,000 pounds per square inch but the per cent of elongation and reduction of area of the tensile specimen is low, showing that the steel has little ability to flow without causing failure. Obviously such a material has little resistance to shock.

On account of the properties just described, high manganese steel is not used in the as cast condition. Hot working improves the properties of the steel to some extent, but the most useful properties are obtained by proper heat treatment.

The customary heat treatment for austenitic manganese steel consists in heating to about 1800-1850 degrees Fahr. followed by quenching in water. The heating causes all of the cementite to become dissolved into the austenite, while the quenching prevents the cementite from again separating out. The structure produced therefore is entirely austenitic.

Properties and Uses of Heat Treated Manganese Steel

The physical properties of heat treated high manganese steel as given by Camp and Francis are:

Tensile Strength, 140,000-150,000 pounds per square inch.
Elastic Limit, 33-35 per cent of the tensile strength.
Elongation, 45-50 per cent
Reduction of Area, 30-40 per cent
Brinell Hardness, About 175.

It will be noted that the tensile strength is quite high and the elastic limit is comparatively low and the figures for ductility

are high. The low Brinell hardness value would indicate that the hardness is not greater than that of an untreated medium carbon steel. However this test is deceptive, because the high manganese steels are very resistant to certain types of wear.

One of the interesting and important properties of austenitic manganese steel is its ability to be hardened by a slight amount of cold work. Any mechanical action such as hammering, pulling, bending, squeezing or twisting which is applied to the metal while cold is described as cold work. Such treatment produces at least a slight amount of flow of the metal and consequently a slight change in the shape of the finished article. It often happens that the amount of cold work which manganese steel parts receive in service, affects only the surface layers of the steel. Consequently the surface becomes hard and resistant to wear while the metal as a whole is tough. The hardening of manganese steel by cold work is probably due to a partial decomposition of austenite into martensite, which is harder than austenite. The following example illustrates the commercial importance of the hardening produced by cold work.

A certain company which manufactures steam shovels tried a number of types of steel for dipper points. Among those tried were hardened medium carbon alloy steels and high manganese steels. The former showed much greater hardness when tested with the ordinary hardness testing instruments. Tests made by shovelling gravel showed that the manganese steel points had a much longer life than the apparently harder steels. On the other hand the manganese steel points had a much shorter life when shovelling sand. The reason seemed to be that the peening action of the gravel produced enough cold work to harden the surface of the manganese steel points making them very resistant to wear. On the other hand the action of the loose sand being wear unaccompanied by cold work, the result was that the manganese steel points wore away rapidly.

One of the disadvantages of high manganese steel is that, due to it great resistance to wear, it can be machined only with the greatest of difficulty or by grinding. Articles made of this type of steel must be cast or forged to approximately the finished size and shape. In at least one instance, however, the lack of machinability may be considered an advantage. High manganese steel is used in the construction of safes on account of its great toughness

and its inability to be drilled. It is a steel which is commonly used for railroad switch points, cross-overs, curved rails, and for many parts of mining, dredging, and crushing machinery. It is also reported as decidedly advantageous in the construction of coke screens. It will be noted that in all of these instances the parts must withstand a combination of wear and impact. In this field the high manganese steels have proved very valuable.

There are parts, however, which must withstand shock and wear for which manganese steel is not so well adapted. On account of the low elasticity limit and the great ductility, high manganese steel flows rather easily under heavy loads. As stated before this flowing of the metal itself produces hardness, but there are some parts which cannot be allowed to change in shape in service. For these parts high manganese steel is not entirely satisfactory for there may be a slight flow of the metal before it becomes hardened. For example one company has reported that high manganese steel did not work out satisfactorily for caterpillar treads because the flowing of the metal caused the rivet holes to change in size and shape. All of the parts previously mentioned as ones commonly made of high manganese steel may be allowed to change in shape slightly without seriously impairing their usefulness.

Another interesting and useful characteristic of high manganese steel is its non-magnetic property. In this respect it is similar to other austenitic steels. This is of importance because there are certain parts of some electrical and magnetic instruments which must not be affected by the magnet. In this connection it is worth mentioning that there has been developed an alloy steel containing about 15.00 per cent nickel and 5.00 per cent manganese which is also non-magnetic. While this steel could not be classified as easily machinable it is more easily machined than the 12.00-13.00 per cent manganese steels and is much cheaper than the non-magnetic nickel steels containing over 30.00 per cent nickel.

In summary, it may be said that the high manganese steels as cast are brittle. After quenching from a high temperature they are non-magnetic and exceedingly tough. After receiving enough cold work to cause a slight flow of the surface of the metal they become extremely resistant to wear. They must be cast or forged to nearly the final size and shape as they can be machined only by grinding. They are used for parts which must withstand a certain amount of shock and extreme conditions of wear and which

may be allowed to change in shape very slightly in service.

Martensitic Manganese Steels

Steels whose composition place then in the middle zone of Guillet's diagram are classified as martensitic. A more complete and scientifically correct diagram given by Guillet and Portevin[3] shows this middle zone divided into three parts. Steels containing less than 0.50 per cent carbon are classified as martensitic; steels containing 0.50-1.00 per cent carbon, martensitic and troostitic; and steels containing 1.00-1.65 per cent carbon, troostitic and cementitic. This diagram also shows the boundaries between the austenitic, martensitic, and pearlitic zones as broad bands instead of sharp lines. These bands may be described as transition zones. Steels whose composition places them in these zones will have mixed structures.

So far as the present discussion is concerned it should be sufficient to divide all manganese steels containing less than 1.60 per cent carbon into three classes as shown in the diagram in Fig. 1. All of the steels which fall in the middle or martensitic zone are inclined to be brittle even in the slowly cooled condition. So far as the writer has been able to learn there is no commercial use for any of the steels in this zone[4]. For this reason a detailed discussion of the structure and properties of steels in this zone may well be omitted.

As shown by the diagram the quantity of manganese necessary to place a steel in the martensitic or brittle zone depends upon the carbon content. According to a literal interpretation of the diagram, the following steels should have the brittle structure:—0.20 per cent carbon, 5.2-11.8 per cent manganese; 0.40 per cent carbon, 4.5-10.2 per cent manganese; 0.80 per cent carbon, 3.0-6.7 per cent manganese; 1.20 per cent carbon, 1.5-3.5 per cent manganese. However as the boundaries of the martensitic zone are really broad bands, these figures may not accurately represent the limits of composition which will produce the brittle structure. It seems to be the common commercial practice to produce steels with manganese content well above or below the limits given for martensitic steels. For example the austenitic manganese steels

[3]Guillet and Portevin: Metallography and Macrography, page 178.

[4]A critic of one of the previous articles in this series took exception to the statement that manganese in certain percentages produced brittleness, but it was noted that none of the examples which he gave of tough manganese steels fell within the limits for martensitic manganese steels.

previously described usually contain over 1.00 per cent carbon and over 10.00 per cent manganese which is 5.00-10.00 per cent higher than the upper limit for a martensitic steel of that carbon content. Similarly some of the popular pearlitic manganese steels contain about 2 per cent manganese with 0.40 per cent of carbon or less, while the lower limit for manganese content of a martensitic manganese steel of 0.40 per cent carbon is 4.50 per cent according to the diagram. Only the non-shrinking tool steels with 1.5 per cent of carbon and the case of carburized 1.50 per cent manganese steels approach the limits given for martensitic steels.

Pearlitic Manganese Steels

The pearlitic manganese steels compose one of the most important but one of the most frequently overlooked branches of the family of manganese steels. These steels contain more manganese than found in the plain carbon steels or other alloy steels of similar carbon contents but they do not contain enough manganese to produce a martensitic structure in the slowly cooled condition. In general it may be said that the pearlitic manganese steels which have found favor commercially contain considerably less manganese than that required to produce a martensitic structure after slow cooling. For example one of the steels described herein contains about 2.00 per cent manganese and 0.40 per cent carbon, while the theoretical upper limit for the manganese content of a pearlitic manganese steel according to Guillet's diagram would be 4.50 per cent. The pearlitic manganese steels will be divided into several classes for discussion.

Non-deforming Tool Steel. The non-deforming tool steels (also known as "non-shrink" and "oil-hardening" tool steels) contain manganese as one of the principal and sometimes the only alloying element. The manganese content usually is about 1.00-1.50 per cent. The steel may or may not contain small amounts (usually less than 1.00 per cent) of one or more of the following elements:—chromium, tungsten, and vanadium. The carbon content varies from 0.90-1.15 per cent. The particular merit of these steels lies in the fact that they may be hardened and tempered with the minimum amount of change of size and shape. These steels must be quenched in oil for hardening. Water quenching would produce britttleness if not cracking. Master gages, taps,

dies and other tools which must hold their size accurately are made from this type of steel.

Pearlitic Manganese Structural Steels. The low and medium carbon pearlitic manganese steels which are used for structural purposes are interesting. These steels usually contain 1.00-2.00 per cent of manganese although sometimes the content of that element is a little higher. The carbon content varies from 0.08 to about 0.55 depend upon the purpose for which the steel is to be used. In considering the physical properties of these steels, it must be remembered that some of the manganese combines with the carbon while the remainder dissolves in the iron. In this respect it has actions similar to that of both chromium and nickel, for chromium strengthens and increases the hardening power of steel by combining with the iron, while nickel strengthens and toughens steel by dissolving in the iron and forming a stronger ferrite. Like nickel, manganese lowers the critical point of steel. It should therefore be expected that steels containing about 1.00-2.00 per cent manganese would be stronger, tougher and have a greater hardening power than the corresponding plain carbon steels.

Medium Carbon Pearlitic Manganese Steel. These steels are recommended for parts requiring strength, toughness and some resistance to wear. A 2.00 per cent manganese steel has much the same properties as a low chromium nickel steel of the same carbon content. The 2.00 per cent manganese steels have the advantage of being somewhat air hardening. It is claimed for the manganese steels that they show a little higher tensile strength and elastic limit in the as rolled or normalized and air-cooled condition than do most of the other alloy structural steels of similar carbon contents. For this reason these steels are sometimes recommended for parts which cannot readily be given a quenching treatment without danger of producing undue strains.

It is also claimed that the 2.00 per cent manganese medium carbon steels develop a resistance to wear that is greater than would be expected from the Brinell hardness reading. In this respect they are said to be somewhat similar to the high or austenitic manganese steels. However the difference between the wear hardness and the Brinell hardenss of the 2.00 per cent manganese steels is not as great as it is in the case of the austenitic manganese steels. For example it has been reported that mine car axles made of steel containing about 1.90 per cent manganese

and about 0.35 per cent carbon showed a Brinell hardness of about 230, but after a short period of service developed a smooth surface which was highly resistant to further wear. The writer has observed that this type of steel machines differently from some of the other medium carbon steels. The chips coming off in a turning operation are such tougher and harder to break and the finish of the machined piece is smoother. It is also claimed for the 2.00 per cent manganese steels that they have a higher tensile strength and elastic limit in proportion to the Brinell hardness than do most of the medium carbon alloy steels.

As already stated these steels are frequently used in the normalized or air cooled condition. They also show good physical properties in the as-rolled condition without any heat treatment. However it has been reported that there is considerable variation in the physical properties in the as-rolled condition due to variations in the rolling mill practice. This may nevertheless present a field which is worthy of further investigation. These steels may also be heat treated by heating to above the upper critical point and quenching either in water or oil, depending upon the part and the properties desired, and tempering at a temperature between 800 and 1200 degrees Fahr. to produce the desired physical properties.

The following paragraphs describe the composition and uses of two of the common types of medium carbon pearlitic manganese steel while the accompanying charts give the physical properties that are produced by rolling, normalizing, annealing and heat treating these steels.

Manganese Steel having a Carbon Content of 0.30-0.40 per cent

Composition:—0.30-0.40 per cent carbon; 1.60-1.90 per cent manganese; sulphur, phosphorus and silicon, low as in other alloy steels.

Uses Recommended:—Automobile axle shafts, connecting rods, steering gear parts, bolts, nuts, sucker rods, bit steel mine car axles, gas cylinders, pipe wrenches, electric locomotive axles, marine engine shafts.

Manganese Steel having a Carbon Content of 0.20-0.30 per cent

Composition:—0.20-0.30 per cent carbon; 1.60-1.90 per cent manganese; sulphur, phosphorus and silicon, low.

Uses Recommended:—Track bolts, stud bolts, clamps, generator and engine shafts, seamless tubing, clutch hubs, spring clips.

Case Hardening Manganese Steels. Steels containing 1.00-1.50 per cent of manganese have also been successfully used for case hardening. Up until a comparatively few years ago man-

ganese steel was not considered suitable for case hardening purposes. This was due primarily to the fact that the 1.25 per cent manganese steel then on the market was too high in carbon to form a good core in case hardened work. At the present time steel is being made containing 1.20-1.50 per cent manganese with a carbon content below 0.15 per cent. The following example

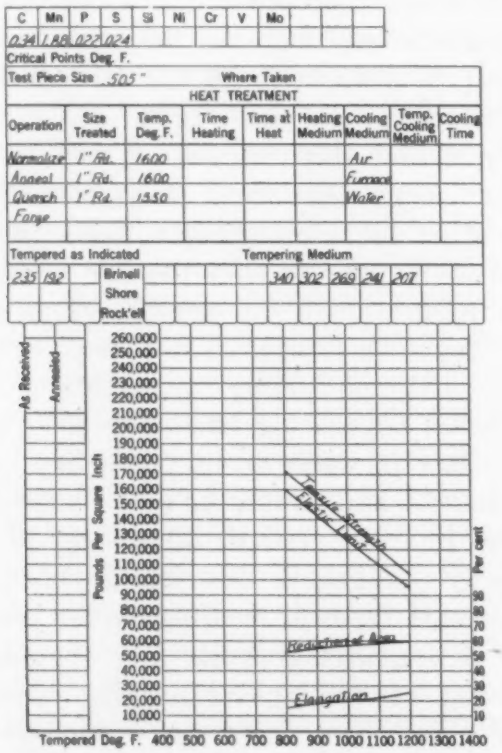


Fig. 2—Physical Properties of 0.34 Per Cent Carbon, 1.88 Per Cent Manganese Steel.

shows, however, that even the older type of manganese steel might prove satisfactory if properly handled.

During the war the Government had a specification for the bolts of the infantry rifle which called for a steel containing about 1.25 per cent manganese and 0.30-0.35 per cent carbon. This steel did not produce enough hardness or shearing strength in the quenched and tempered condition and the carbon content was higher than usually specified for case hardening. Efforts to case harden bolts made of this steel resulted in the production of a considerable number of brittle bolts which broke in proof firing. Examination of the bolts that failed showed that the cores were quite hard. This was due to the fact that the carbon being as high as

0.35 per cent there was not as much difference between the critical temperature of the core and the case as there is in most case hardening steels. Furthermore the manganese content lowered the critical point and increased the hardening power of the steel. The final quenching temperature employed was the same as customarily used for plain carbon case hardening steel and consequently the

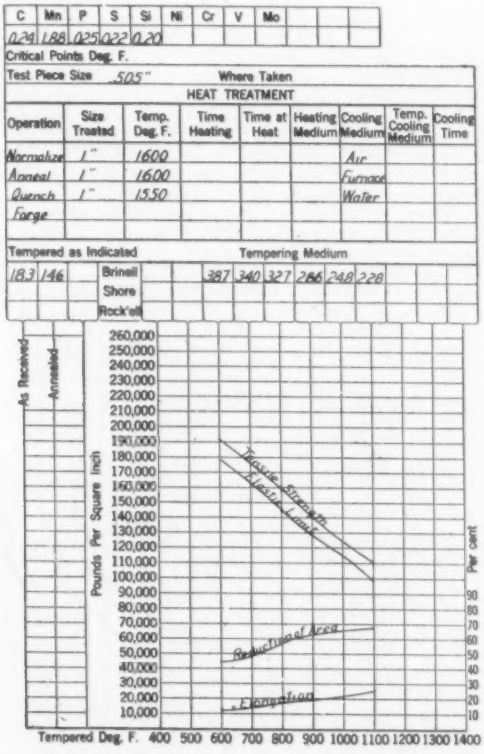

C Mn P S Si Ni Cr V Mo
0.24 1.88 0.25 0.22 0.20
Critical Points Deg. F.
Test Piece Size .505" Where Taken
HEAT TREATMENT
Operation | Size Treated | Temp. Deg. F. | Time Heating | Time at Heat | Heating Medium | Cooling Medium | Temp. Cooling Medium | Cooling Time
Normalize 1" 1600 Air
Anneal 1" 1600 Furnace
Quench 1" 1550 Water
Forge
Tempered as Indicated
Tempering Medium
183 146 Brinell 387 340 327 286 248 228
Shore
Rock'ell
As Received
Annealed
Pounds Per Square Inch
260,000 250,000 240,000 230,000 220,000 210,000 200,000 190,000 180,000 170,000 160,000 150,000 140,000 130,000 120,000 110,000 100,000 90,000 80,000 70,000 60,000 50,000 40,000 30,000 20,000 10,000
Tensile Strength
Yield Point
Reduction of Area
Elongation
Per cent
90 80 70 60 50 40 30 20 10
Tempered Deg. F. 400 500 600 700 800 900 1000 1100 1200 1300 1400

Fig. 3—Physical Properties of 0.24 Per Cent Carbon, 1.88 Per Cent Manganese Steel.

treatment had a hardening effect upon the core of the manganese steel bolts. It was found, however, that by properly controlling the carburizing temperature, quenching directly from carburizing, reheating accurately to almost the lowest possible hardening temperature, quenching and tempering, perfectly satisfactory bolts could be produced. In the mean time the steel specifications had been changed but before the new steel arrived, case hardened manganese steel bolts were being produced which withstood a proof firing pressure of about three times the service pressure. This illustration is not given as a recommendation for the use of 0.35 per cent carbon manganese steel for case hardening, but to show what can be accomplished by proper heat treating.

It sometimes happens that parts which are made of what is supposed to be plain carbon steel, but which unintentionally contains 1.00 per cent of manganese or more, are found to be brittle after case hardening. This brittleness is frequently charged to the high manganese content. As a matter of fact the trouble probably lay in the fact that the case hardening treatment given might

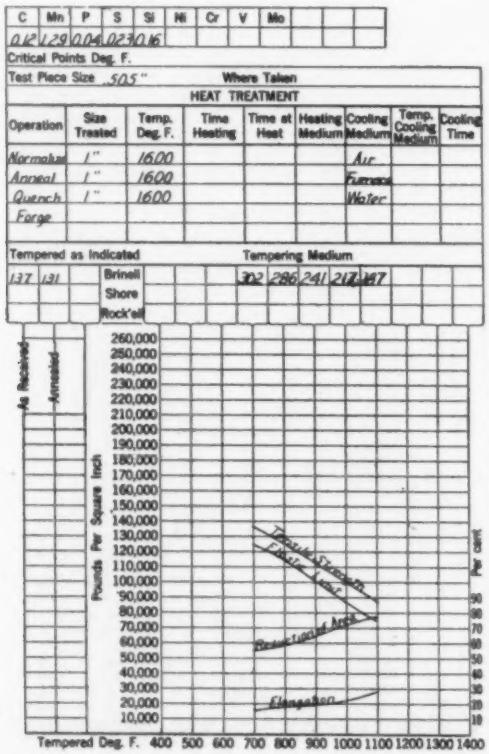

C Mn P S Si Ni Cr V Mo
0.12 1.29 0.04 0.23 0.16
Critical Points Deg. F.
Test Piece Size .505" Where Taken
HEAT TREATMENT
Operation | Size Treated | Temp. Deg. F. | Time Heating | Time at Heat | Heating Medium | Cooling Medium | Temp. Cooling Medium | Cooling Time
Normalize | 1" | 1600 | Air
Anneal | 1" | 1600 | Furnace
Quench | 1" | 1600 | Water
Forge
Tempered as Indicated
Tempering Medium
137 131 Brinell 302 286 241 217 197
Shore
Rock'well
As Received
Annealed
Pounds Per Square Inch
260,000 250,000 240,000 230,000 220,000 210,000 200,000 190,000 180,000 170,000 160,000 150,000 140,000 130,000 120,000 110,000 100,000 90,000 80,000 70,000 60,000 50,000 40,000 30,000 20,000 10,000
Tensile Strength
Elastic Limit
Reduction of Area
Elongation
Per cent
90 80 70 60 50 40 30 20 10
Tempered Deg. F. 400 500 600 700 800 900 1000 1100 1200 1300 1400

Fig. 4—Physical Properties of 0.12 Per Cent Carbon, 1.29 Per Cent Manganese Steel.

have been suitable for a plain carbon steel but not suitable for a manganese steel.

One of the modern case hardening manganese steels is made to the following chemical specification.

	Per Cent
Carbon	0.08-0.15
Manganese	1.20-1.50
Sulphur	0.04 maximum
Phosphorus	0.04 maximum

In such a steel the manganese increases the strength of the core and the hardness of the case, providing it is given the proper case hardening treatment. In case hardening this type of steel it is

probably best to quench in oil directly from the carburizing heat in order to prevent the segregation of manganese carbide in the outer layer of the case, for such a segregation once formed is difficult to break up by further heat treatments. The high quench should be followed by reheating to the proper temperature to refine the case, quenching and tempering. As manganese lowers the

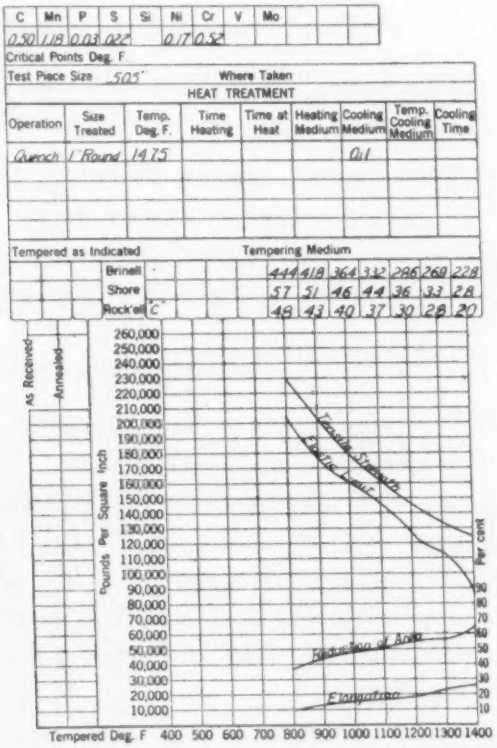


Fig. 5—Physical Properties of 0.50 Per Cent Carbon, 1.18 Per Cent Manganese Steel.

critical point the final quench may be lower than that used for plain carbon steel. Quenching in oil is frequently recommended.

It is difficult to give any exact figures for the physical properties of case hardened work because a great deal depends upon the ratio of the case depth to the entire cross-sectional area of the piece. The accompanying diagram (Fig. 4) shows the physical properties produced by heating, quenching and tempering.

Pearlitic Manganese Steel Castings

An interesting report showing the value of manganese in steel castings is given by the Illinois University Experiment Station.[5]

[5]Bulletin 156, University of Illinois Experiment Station.

In this report are given figures for the physical properties produced by casting and heat treating two types of steel castings, designated 81 and 82. The chemical composition of these two types of material are as follows:

	No. 81 Per Cent	No. 82 Per Cent
Carbon	0.352	0.250
Manganese	1.71	0.68
Silicon	0.30	0.32
Phosphorus	0.021	0.012
Sulphur	0.030	0.032

It will be noted that No. 81 may be classified as a pearlitic manganese alloy while No. 82 is a plain carbon steel. The tests showed that the manganese steel gave better physical properties. The effects of several heat treatments were described but only a few will be given here.

High Sulphur Manganese Steel

Comparatively recently there has appeared on the market a group of steels, which it is claimed possess superior machining properties combined with good values for strength and toughness. While the writer has not been able to obtain definite figures for chemical specifications for these steels it is his understanding that their properties are due to the fact that the sulphur and the manganese contents are higher than ordinarily found in the plain carbon open hearth steels.

It has long been recognized that screw stock which usually contains 0.075-0.150 per cent sulphur is one of the easiest types of steel to machine. There are two common types of screw stock for which the S. A. E. gives the following specifications:—

	Bessemer S. A. E. 1112 Per Cent	Open-Hearth S. A. E. 1120 Per Cent
Carbon	0.08 -0.16	0.15 -0.25
Manganese	0.60 -0.80	0.60 -0.90
Sulphur	0.075-0.15	0.075-0.15
Phosphorus	0.09 -0.13	0.06 maximum

While these steels machine well, they are not usually recommended for forging or for case hardening as they are likely to prove brittle. The Bessemer screw stock in particular is likely to contain more or less non-metallic impurities which embrittle the

steel. Exactly how much of the brittleness is due to the sulphur and how much is due to the phosphorus and the other impurities is a subject which is under dispute. Some writers claim that sulphur up to 0.10 per cent is not injurious if it is present entirely in the form of manganese sulphide. Others claim that while such a sulphur content may not be injurious if the steel is well made

Physical Properties of Manganese and Plain Carbon Steel Castings Before and After Heat Treating

Steel No.	Heat Treatment	Elastic Limit, lbs./in.²	Tensile Strength, lbs./in.²	Elongation in 2 in., Per Cent	Reduction of Area, Per Cent	Charpy Impact Test, Ft. Lbs.	Repeated Impact Test, No. of Blows	Brinell Number	Endurance Limit,[1] lbs./in.²	Endurance Ratio[2]
81 Mn	As received (Cast condition)	39,000	80,800	2.1	4	2.8	30	179	32,000	0.40
82 Carbon	As received (Cast condition)	23,600	67,200	22.0	33	20.1	209	119	27,000	0.40
81 Mn	Heat to 1650° F., hold one hour, cool in air	42,400	108,900	14.4	26	20.2	491	197	45,000	0.41
82 Carbon	Heat to 1625° F., hold one hour, cool in air	42,800	76,600	30.5	51	32.6	279	136	35,000	0.46
81 Mn	Heat to 1650° F., hold one hour, cool in air; reheat to 1000° F., hold one hour, cool in air	59,600	103,600	22.5	48	30.7	511	188	45,000	0.43
82 Carbon	Heat to 1625° F., hold one hour, cool in air; reheat to 1000° F., hold one hour, cool in air	41,300	76,100	31.7	56	34.0	291	133	33,000	0.43

CHEMICAL ANALYSIS

	81 Mn Steel	82 Carbon Steel
Carbon	0.352	0.250
Manganese	1.71	0.68
Silicon	0.30	0.32
Phosphorus	0.021	0.012
Sulphur	0.030	0.032

[1]The endurance limit is the pounds per square inch maximum fibre stress that a rotating beam will stand indefinitely without failure.

[2]The endurance ratio is the ratio of the endurance limit to the tensile strength.

The data for this table was taken from Table II, Illinois University Experiment Station Bulletin No. 156. The arrangement is slightly different.

and the sulphide particles are small and well distributed, the high sulphur content may be objectionable if the sulphides segregate in spots.

It is claimed for the new steels that they are exceptionally clean and sound and that the only non-metallic inclusions which

they contain to any extent are the manganese sulphide inclusions. It is also claimed that the machinability compares favorably with that of Bessemer screw stock. The new steels are furnished with four carbon contents varying from 0.10-0.20 per cent to 0.30-0.40 per cent. The steel with the lowest carbon content is recommended for case hardening. It is claimed that the properties produced by case hardening will be superior to those produced when an ordinary plain carbon steel is used. The steels with the higher carbon contents are recommended for forging and heat treating. The particular merit claimed for all of these steels is greater machinability. If the assumption is correct that these steels are open-hearth steels containing higher sulphur and manganese than usually found in plain carbon open-hearth steels, it should be expected that the manganese content would assure that the sulphur would be present in the less objectionable form of manganese sulphide. The remainder of the manganese should have the same effect upon the steel as described in the paragraphs on pearlitic manganese steel.

Chromium-Manganese Steels

Pearlitic manganese steels are also made containing chromium and sometimes nickel in addition to the manganese as alloying elements. There is one family of such steels on the market which contain about 1.10 per cent manganese, and about 0.50 per cent chromium. This type of steel is made with varying carbon contents depending upon the purpose for which the steel is to be used. A steel containing about 0.15-0.20 per cent carbon is recommended for case hardening. A steel containing about 0.50 per cent carbon when properly heat treated gives high tensile strength and elastic limit combined with considerable toughness. Fig. 5 shows in a graphic form the typical physical properties produced by heat treating such a steel. A similar steel containing about 0.30-0.40 per cent carbon while it does not develop such high physical properties is more easily machined and is suitable for many purposes. The steels are recommended for much the same purposes as the other alloy steels of low and medium carbon contents.

Silico-Manganese Spring Steel

Two classes of silico-manganese spring steel which are mentioned in the S. A. E. specifications have the following chemical composition.

	S. A. E. 9250 Per Cent	S. A. E. 9260 Per Cent
Carbon	0.45-0.55	0.55-0.65
Manganese	0.60-0.90	0.60-0.90
Silicon	1.80-2.20	1.80-2.20
Sulphur	0.045 max.	0.045 max.
Phosphorus	0.045 max.	0.045 max.

It will be noted that the maximum manganese content of these steels is only 0.10 per cent higher than that of other alloy medium carbon steels. It may well be argued that these should not be classed as manganese alloy steels. Manganese is probably mentioned in the name of these steels because the manganese content is higher than in the plain carbon spring steels. Such steels usually contain higher carbon and lower manganese than that given above. The silico-manganese spring steels have the advantage over the plain carbon steels in that the elastic limit after heat treating is higher.

Summary

Manganese is found in all types of steel. Only when the content is higher than usual is the steel considered a manganese alloy steel. Even the small amount of manganese found in plain carbon steels has an affect upon their physical properties. Manganese is also used as a cleaner and as an antidote for some of the evil effects of sulphur.

Manganese alloy steels may be divided into four classes; austenitic, martensitic, pearlitic, and cementitic. Only the austenitic and the pearlitic are at present of commercial importance. The austenitic or high manganese steels require heat treatment. When properly heat treated they are non-magnetic, tough and resistant to wear, involving a small amount of cold work. The pearlitic manganese steels may be divided into high, medium and low carbon grades. The high carbon is used for non-deforming tool steel; the medium carbon grade for parts requiring strength and toughness and the low carbon grade for case hardening. Low and medium carbon grades of pearlitic manganese steel are also made with the addition of nickel and chromium. Silico-manganese steel is used for springs.

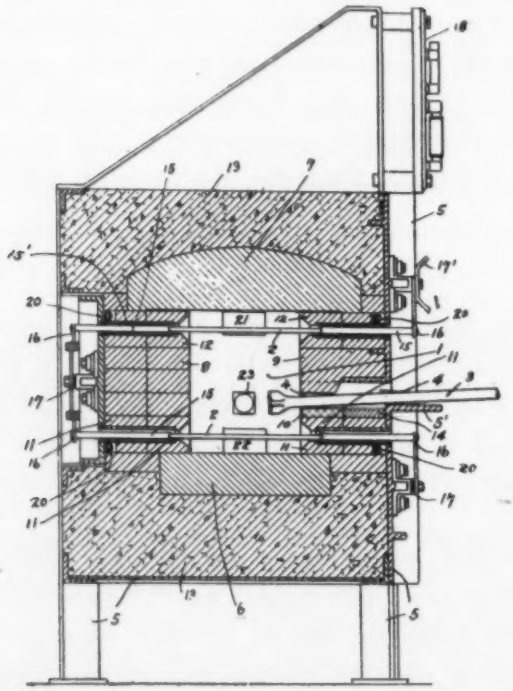
Note—The writer wishes to express his appreciation of the co-operation of A. O. Fulton of the Wheelock Lovejoy & Co., and Messrs. W. E. Davis and O. L. Pringle of the Pittsburgh Crucible Steel Co. in furnishing certain data and information for this article.

Reviews of Recent Patents

By NELSON LITTELL, Patent Attorney
475 Fifth Ave., New York City—Member of A. S. S. T.

1,628,964, Drill-Heating Furnace, Harold K. Fox, of Fresno, California.

This patent describes an electric furnace for heating drills or the like, comprising the refractory chamber 1, through which the electrodes 2 pass near the top and bottom, and which is provided with a slot 4 to receive the drill bits 3. The slot is enlarged at each end to permit the insertion and removal of the



drill bits which are moved from end to end of the slot during the heating. The water pipes 20 are to prevent overheating of the electric terminals. Observation and cleaning openings 21 and 22 are located at each end of the chamber and 23 indicates a location for a pyrometer in the heating zone.

1,629,072, Composition for and Method of Coating Metal Surfaces, Ralph R. Danielson, of Chicago, Ill.

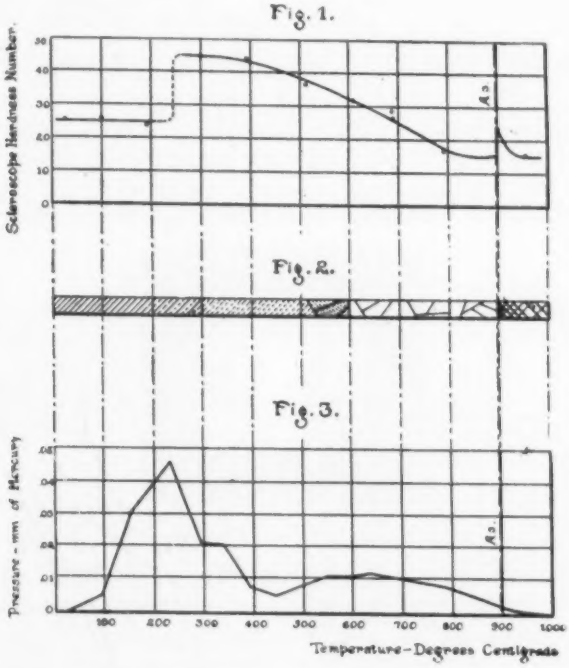
This patent describes a refractory coating for selective carburization of metal surfaces. The patent is dedicated to the public and may be used by anyone without the payment of royalties. The coating is composed of a frit consisting of flint 69.90, borax 36.96, sodium nitrate $NaNi_3$ 6.95 and lead oxide Pb_3O_4 8.17, which is first sintered at 850 to 900° C. and is then powdered and sieved. 100 parts of the powdered frit is mixed with 93 parts

of clay and sufficient water to give a coating of the consistency of ordinary enamel. The material is applied by painting or dipping the clean metal surfaces and will not spall off during the carburizing, but readily cracks during cooling and may be easily removed.

1,630,449, **Heat Treatment of Electrolytically Deposited Iron, Norman B. Pilling, of Wilkinsburg, Pennsylvania, Assignor to Westinghouse Electric & Manufacturing Company, a corporation of Pennsylvania.**

This patent describes the reclaiming of undersized or worn machine parts by building up layers of electro-deposited iron on the parts and the heat-

Fig. 1.



treating of the electro-deposited layer to render it softer and tougher. Figures 1 and 3 indicate, respectively, the change in hardness, due to heating and the evolution of hydrogen in the iron during the heat treatment. Figure 2 is a diagrammatic illustration of the structural changes which take place. The best results for the electro-deposited iron is to heat to a temperature between 250 degrees to 450 degrees Cent.

1,629,699, **Process of Improving Aluminum Alloys, William Guertler, of Charlottenburg, and Wilhelm Sander, of Essen, Germany, Assignors to the Firm: Th. Goldschmidt A. G., of Essen Germany.**

This patent relates to an improvement in aluminum-zinc-magnesium alloys in which the zinc and magnesium are present in proportions to form the compound $MgZn_2$. With this constituent the improvement in the tensile strength of the alloy commences with the presence of about 4 per cent of $MgZn_2$ and about 26 per cent of $MgZn_2$ makes the alloy too hard and crystalline for practical use. The desirable percentages are between 4 and 12

per cent by weight of $MgZn_2$. Heat treatment for the mechanically worked alloy is to anneal from 15 to 60 minutes around 500 degrees Cent. (932 degrees Fahr.) quench in water and self-age for about 5 days.

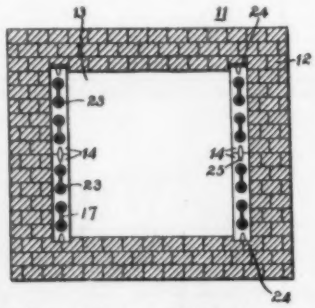
1,628,990, Alloy, Francis F. Lucas, of East Orange, New Jersey, Assignor to Western Electric Company, Incorporated, of New York, N. Y., a corporation of New York.

This patent describes a non-magnetic and non-corrodible alloy steel suitable for cable armor, which is preferably within the following composition:

Nickel	7 to 9	Manganese	4
Tungsten	9	Carbon	0.60
Chromium	6	The remainder iron	

1,632,318, Electric Heating Unit, Frank C. Simms, of East Palestine, Ohio.

This patent describes an improvement in electric furnaces in which the resistor-support material is of heat and electric-conducting material, such as carborundum. The furnace comprises the usual walls of brick or the like 12



enclosing the furnace chamber 13 in which the resistor-supporting blocks 14 of carborundum are mounted, each having a plurality of passages therethrough for the resistance members 17 which extend through holes 23 in the block 14, the holes being lined with ceramic insulating tubes, the blocks 14 being of heat and electric-conducting material are uniformly heated throughout and provide a uniform heating of the furnace chamber at all points.

1,632,704, Casting Having Chromium Alloy Surface, Charles B. Jacobs, of Wilmington, Delaware, Assignor, By Mesne Assignments, to Electro Metallurgical Company, a corporation of West Virginia.

This patent describes a method of producing castings which are resistant to the oxidation of furnace gases at high temperatures and the like, having a high chromium alloy surface. In the production of these castings, the mold is formed in the usual way and is coated with powdered metallic chromium bound together with the use of silicate of soda. The coating is painted or washed on to a thickness of about ¼ of an inch, the mold is baked and the metal, which may be iron or steel, poured in the usual manner. The molten metal penetrates the chromium coating and alloys therewith forming a surface which may run 38 to 39 per cent of chromium on the surface and as much as 9 per cent chromium ⅛ of an inch in from the surface. The usual alloys for cast iron or steel are used for both castings.

THE ENGINEERING INDEX

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Arrangements have been made with The American Society of Mechanical Engineers whereby the American Society for Steel Treating will be furnished each month with a specially prepared section of The Engineering Index. It is to include items descriptive of articles appearing in the current issues of the world's engineering and scientific press of particular interest to members of the American Society for Steel Treating. These items will be selected from the copy prepared for the annual volume of the Index published by the A. S. M. E.

In the preparation of the Index by the staff of the A. S. M. E. some 1,200 domestic and foreign technical publications received by the Engineering Societies Library (New York) are regularly searched for articles giving the results of the world's most recent engineering and scientific research, thought, and experience. From this wealth of material the A. S. S. T. will be supplied with a selective index to those articles which deal particularly with steel treating and related subjects.

Photostatic copies (white printing on a black background) of any of the articles listed may be secured through the A. S. S. T. The price of each print, up to 11 by 14 inches in size, is 25 cents. Remittances should accompany orders. A separate print is required for each page of the larger periodicals, but whenever possible two pages will be photographed together on the same print. When ordering prints, identify the article by quoting from the Index item: (1) Title of article; (2) name of periodical in which it appeared; (3) volume, number, and date of publication of periodical; and (4) page numbers.

ALLOY STEELS

Ac_1 RANGE. The Ac_1 Range in Special Steels, J. H. Andrew and H. A. Dickie. Iron & Steel Inst.—advance paper, no. 1, for mtg., May 1927, 35 pp., 38 figs. Investigation to throw light on extent of, and reactions involved in Ac_1 range; effect of heat treatment on specific volume.

ALLOYS

EUTECTIC, STRUCTURE OF. The Application of Strain Methods to the Investigation of the Structure of Eutectic Alloys, F. Hargreaves. Inst. of Metals—advance paper no. 421, for mtg. Mar. 9-10, 1927, 3 pp., 11 figs. Investigation of lead-tin, tin-zinc, and copper-silver eutectics shows that straining by suitable methods results in markings due to slip, similar to those which occur in case of pure metals; orientation of lead-tin eutectic is apparently determined by that of tin.

MAGNETIC ANALYSIS OF NON-MAGNETIC. Magnetic Analysis as a Means of Studying the Structure of Non-Magnetic Alloys, K. Honda and H. Endo. Inst. of Metals—advance paper, no. 415, for mtg., Mar 9-10, 1927, 21 pp., 23 figs. Investigation shows, by means of examples, that magnetic analysis applied to case of non-magnetic elements, which are paramagnetic or diamagnetic, affords a very convenient method of studying equilibrium diagram for alloys consisting of these elements; not only is melting point or transformation point of element given by a sharp discontinuity of susceptibility-temperature curve, but liquidus and solidus of alloy are also marked by a sharp break or bend in same curve; magnetic analysis is also a very convenient method for study of actual state of alloy when above its melting point, that is, in detecting existence of intermetallic compound in liquid phase, the degree of dissociation of compound with rise of temperature, etc.

ALUMINUM

CRYSTALS. Technical Properties of Aluminum Crystals (Die Technologischen Eigenschaften von Aluminiumkristallen), G. Sachs. V. D. I. Zeit., vol. 71, no. 17, Apr. 1927, pp. 577-584, 37 figs. Analysis of deformation of crystals; elastic limit and strain hardening; strength and elongation; tensile strength; slip phenomena at room temperature and at high temperatures; recrystalization.

SILICON DETERMINATION. Is there a safe Method for the Determination of Silicon Dioxide in the Presence of Silicon in the Analysis of Aluminum (Gibt es ein sicheres quantitatives Verfahren, um SiO_2 neben Silicium bei der Analyse des Aluminiums zu bestimmen?), Prettner. Chemiker Zeitung, vol. 51, no. 27, p. 261. Calls attention to sensitivity of silicon at high temperatures in analysis of aluminum.

ALUMINUM BRONZE

IMPROVEMENT. The Improvement of Aluminum Bronze as an Engineering Material, R. C. Reader. Am. Foundrymen's Assn.—advance paper, no. 17, for mtg. June 6-10, 1927, 9 pp. Deals with influence of added elements; effects of addition of iron, nickel, manganese; use of chill castings; casting and mold temperatures; mold designs and position of casting in mold; position of feeder heads; heat treatment.

BLAST FURNACES

BRITISH PRACTICE. British Blast-Furnace and Cupola Practice, J. E. Fletcher. Brit. Cast Iron Research Assn.—Bul., no. 16, Apr. 1927, pp. 6-10. Just as proportions of blast furnace and speed of fuel burning must vary for special conditions of burden (chemical and physical composition, etc.) so in cupola design and operation must follow such variations in physical and chemical composition of fuel and metal charges; in both

cases fuel consumption per ton of product is affected by amount of slag required to assist desulphurization of metal and for fluxing of earthy matters in fuel and carried by pig iron and scrap.

GASES AND ORE INTERACTION. The Interactions of Gases and Ore in the Blast-Furnace, W. A. Bone, L. Reeve and H. L. Saunders. Engineering, Vol. 123, no. 3199, May 6, 1927, pp. 564-566, 8 figs. Experiments to ascertain by best laboratory methods available, facts concerning interactions between oxides of carbon, when diluted with much the same proportion of nitrogen as in blast-furnace gas, and oxides of iron, at temperatures between 380 deg. and 650 deg. cent. which is an important range from point of view of "carbon deposition" in furnace. Paper read before Iron and Steel Inst.

GREAT BRITAIN. Blast Furnaces of the United Kingdom Built and in Blast. Foundry Trade Jl., vol. 35, no. 559, May 5, 1927, supp. plate. Quarterly statistical report.

LARGE HEARTHS. The Operation of Large Hearth Furnaces Using Coke Made from One Hundred Per Cent. High Volatile Coal, J. E. Lose. Am. Iron & Steel Inst.—advance paper, for mtg., May 20, 1927, 23 pp., 4 figs. Development of blast furnace hearth, credit for which rests with Edgar Thomson Plant of Carnegie Steel Co., and later with South Chicago Plant of Illinois Steel Co., dates back over two decades; history of development, including analysis of operating difficulties and steps taken to overcome them; blast temperature; flue dust produced and consumed; movement of furnace.

IRON SCRAP IN. An Expression of Views on the Use of Iron Scrap in the Blast Furnace, D. McLain. Am. Foundrymen's Assn.—advance paper, no. 11, for mtg. June 6-10, 1927, 6 pp. Its effects upon product as used by foundries.

PRACTICE. Blast Furnace Practice at Consett Iron Co., Ltd., C. S. Gill. Foundry Trade Jl., vol. 35, no. 557, Apr. 21, 1927, pp. 331-334, and (discussion) vol. 35, no. 558, Apr. 28, 1927, pp. 360-362. There are eight blast furnaces, seven of which date from 1873 to 1880 and one modern furnace capable of making up 2500 tons of pig iron per week without addition of scrap to charge; bell and hopper system of lowering material into furnaces is used, and bell is operated by compressed air; materials used; reactions in furnace; materials produced; influence of constituents on pig iron.

THEORY. The Theory of the Blast Furnace, R. Franchot. Am. Iron & Steel Inst.—advance paper, for mtg., May 20, 1927, 18 pp. Blast furnace as gas producer; disposition of hearth heat.

BOILER PLATE

EMBRITTLEMENT. Embrittlement of Boiler Plate, S. W. Parr and F. G. Straub. Indus. & Eng. Chem., vol. 19, no. 5, May 1927, pp. 620-622, 5 figs. Investigation undertaken by Engineering Experiment Station of University of Illinois in co-operation with group of public utilities of Middle West for purpose of obtaining information of general interest to all; cause of intercrystalline failures; prevention of embrittlement.

BRASS

EARLY HISTORY. The Early History of Brass Making, M. Cook. Metal Industry, vol. 30, no. 18, May 6, 1927, pp. 453-454. Use of calamine; early brass-melting practice; brass in England.

15TH-CENTURY. Examination of a Fifteenth-Century "Brass," J. N. Friend and W. E. Thorneycroft. Inst. of Metals—advance paper, no. 420, for mtg., Mar. 9-10, 1927, 2 pp., 3 figs. Brief account of tomb of Richard Beauchamp at Warwick and analysis and micrographs of portions of bronze statue are given.

GASES IN. Gases Contained in Brasses, Aluminum and Its Alloys (Sur les gaz contenus dans les laitins, l'aluminium et ses alliages), L. Guillet and A. Roux. Academie des Sciences—Comptes Rendus, vol. 1, no. 12, Mar. 21, 1927, pp. 724-727. Gases are evolved from brasses containing copper and zinc, between 530 and 1040 deg. maximum rate occurring at 720-790 deg. and principally at 930-980 deg.; volume of gas was half that of metal; aluminum containing silicon and iron evolved 0.14 of its volume of gas between 400 and 550 deg.; physical properties of metal were same whether annealing was carried out in air or in vacuo.

SHEET. Physical Properties and Methods of Tests for Sheet Brass, H. N. Deusen and L. I. Shaw and C. H. Davis. Am. Soc. Testing Matls.—advance paper, no. 32, for mtg, June 20-24, 37 pp., 19 figs. Investigation to secure simple and reliable method of test of thin-sheet non-ferrous metals; considerable attention given to Rockwell tester, which, as result of this work, has been found satisfactory for use as a specification instrument for brasses 0.020 in. and thicker, when used under standardized methods of test and calibrated in terms of a standard instrument; other tests, such as Meyer's analysis and Amsler reverse bend test, show some promise of adaptation to this problem but further development is necessary.

BRONZES

CASTING. Metal Casting in Repair Shops in Chemical Industry (Ueber Metallgiesserei in der Reparaturwerkstatt chemischer Betriebe, W. Meysahn. Chemiker-Zeitung, vol. 51, no. 33, Apr. 27, 1927, pp. 309-310. Deals with production of bronze castings such as spindles, bearings, valve seats, etc.

IMPURE. Phenomena Observed in Impure Bronze (Phénomènes Recontrés dans les Bronzes Impurs), E. Decherf. Revue Universelle des Mines, vol. 14, no. 1, Apr. 1, 1927, pp. 30-31, 3 figs. Points out deteriorating effect of aluminum in bronzes.

CAST IRON

ANALYSIS. Method of Rapid Analysis of Cast Iron (Méthode d'Analyse Rapide d'une Fonte), M. Cymboliste. Fonderie Moderne, vol. 21, Apr. 25, 1927, pp. 82-85. Simultaneous determination of silicon, phosphorus and manganese; determination of carbon and sulphur; solutions and liquors used for these determinations.

CARBON AND SILICON IN. Carbon and Silicon in Cast Iron, A. E. Allinson. Foundry Trade Jl., vol. 35, no. 560, May 12, 1927, pp. 397-399, 8 figs. It would appear that proportions of pearlite and ferrite de

pend upon two factors, casting temperature of metal and its silicon content; pearlitic iron.

CHROMIUM AND NICKEL IN. The Effects of Chromium and Nickel in Cast Iron, R. S. Poister. Am. Foundrymen's Assn. advance paper, no. 8, for mtg. June 6-10, 1927, 21 pp., 3 figs. Deals largely with effect of chromium additions; summary of results of earlier investigators which appear to definitely establish that 0.50 per cent chromium in presence of 1 to 2 per cent silicon increases tensile and transverse strengths and hardness of cast iron; more recent work has generally verified results of earlier investigations and it has also yielded data relating to improvements other than increased physical strength; chromium benefits are stated to be best obtained by silicon adjustment; practical applications and methods of making cupola and ladle additions.

DESULPHURIZING. The refining and Desulphurizing of Cast Iron (Affinage et désulfuration de la fonte), E. Hamélius. Fonderie Moderne, vol. 21, Apr. 10, 1927, pp. 56-57, 4 figs. Describes method of refining which has for its object reduction of inclusions and obtaining homogeneous casting with improved mechanical properties.

DESULPHURIZING. Desulphurizing Action of Manganese in Iron, C. H. Herty and J. M. Gaines, Jr. Iron & Steel of Canada, vol. 10, no. 4, Apr. 1927, pp. 116-118. In order to ascertain extent of and factors controlling this elimination in ladle, several casts were sampled carefully at blast furnace, and, again, when ladles were being emptied, either at mixer, open hearth, or foundry; extent of elimination of sulphur; effect of temperature and time; percentage elimination of sulphur; effect of blast-furnace slag in ladle.

DESULPHURIZING. Sulphur and Desulphurisation in Cast Iron, R. T. Rolfe. Iron & Steel Industry & Brit. Foundryman, vol. 1, no. 1, Apr. 1, 1927, pp. 3-6, 2 figs. Problem of sulphur in foundry practice, extent to which it is prejudicial, extent to which it may be harmless, and associated problem of desulphurization, its ways and means.

DEVELOPMENTS. Recent Developments in Cast Iron and Foundry Practice. Brit. Cast Iron Research Assn.—Bul., no. 16, Apr. 1927, pp. 20-25. Regularity of cupola-melted cast iron; tests by Society of German Iron Founders to determine strength properties that should be prescribed in deliveries of cast iron.

ELEMENTS, ORDER OF. Standardization of Order of Elements in Cast Iron. Brit. Cast Iron Research Assn.—Bul., no. 16, Apr. 1927, p. 19. Suggests order of expressing elements in cast iron which should be adopted as standard for general use.

ENDURANCE UNDER STRESS. Tests of the Endurance of Gray Cast Iron Under Repeated Stress, H. F. Moore and S. W. Lyon. Am. Soc. for Testing Matls.—advance paper, no. 35, for mtg., June 20-24, 1927, 15 pp., 10 figs. Tests of four gray cast irons, including tension, compression, Charpy impact, Brinell hardness and rotating-beam fatigue tests; new form of tension test specimen was used; fatigue tests showed fairly well marked endurance limit for each of cast irons, but in each case endurance limit was low, and ratio of endurance limit to tensile strength was lower than is usually found for steel; fatigue strength was markedly increased by oft-repeated stress below endurance limit; grooves reduced endurance limit but small amount.

FATIGUE TESTS. Fatigue Tests of Cast Iron, H. F. Moore and S. W. Lyon. Am. Foundrymen's Assn.—advance paper, no. 1, for mtg. June 6-10, 1927, 16 pp., 12 figs. Fatigue tests under reversed bending have been made on specimens from four lots of gray cast iron; for each lot there was found definite endurance limit, or fatigue limit, that is stress below which metal would apparently withstand an indefinitely large number of repetitions of stress without fracture; in each case fatigue limit was low whether measured in pounds per sq. in. or by comparison with tensile strength; tensile, compression, Brinell and impact tests were made; special form of tension test specimen was used; metallographic examinations and chemical analyses.

GRAPHITE FORMATION. Some Graphite Formations in Gray Cast Iron, J. W. Bolton. Am. Foundrymen's Assn.—advance paper, no. 3, for mtg. June 6-10, 1927, 20 pp., 18 figs. Discusses various formations of graphite found in cast iron and causes for such formations; five forms are listed: (1) broad straight flake; (2) rosette or whorl; (3) dendritic striation; (4) grouped formation consisting of clear dendritic lakes, peninsulas being filled with fine graphite flakes, and (5) rounded temper carbon; importance of microscopic examination is stressed and three-dimensioned conception is emphasized; distribution of graphite.

GRAPHITE FORMATION. The Constitution of Steel and Cast Iron, F. T. Sisco. Am. Soc. Steel Treat.—Trans., vol. 11, no. 6, June 1927, pp. 986-996, 5 figs. Formation of Graphite in cast iron; typical structures of gray iron containing graphite; size and distribution of graphite particles and amount of cementite in matrix are discussed in their relation to physical properties of cast iron; theory of graphitization of cementite is viewed in its effects on equilibrium diagram and constitutional changes of iron-carbon alloys.

GROWTH. The Growth of Cast Iron, J. H. Andrews. Am. Foundrymen's Assn.—advance paper, no. 16, for mtg. June 6-10, 1927, 12 pp., 2 figs. From work of others and his own, author has come to following conclusions respecting underlying causes of growth in cast iron; (1) by graphitization of combined carbon; (2) by percolation of air through graphite flakes and channels in iron bringing about oxidation of ferrite, with formation of Fe_3O_4 and probably finely deposited carbon; (3) certain amount of contraction will eventually result from oxidation of graphite and deposited carbon, but this may be balanced by further and continuous oxidation of ferrite; (4) every time iron is heated and cooled its structure will be changed with result that coefficient of expansion will have altered; author does not think that occluded gases, or rather their physical effect, can bring about permanent expansion.

HANDLING AND MELTING. Handling and Melting Gray Iron. Iron Age, vol. 119,

no. 22, June 2, 1927, pp. 1587-1590, 5 figs. Washing-machine plant has several novel features in continuous-pour foundry; double-magnet crane.

HEAT TREATMENT. The Heat Treatment of Gray Cast Iron and Semi-Steel, O. W. Potter. Foundry Trade Jl., vol. 35, nos. 559 and 561, May 5 and 19, 1927, pp. 371-374 and 413-416, 26 figs. May 5: Research was made to obtain definite data of properties involved along with chemical analyses and microscopic study; chemical analysis; transverse tests; tensile tests.

IMPROVEMENT. Improvement of Cast Iron (Die Veredlung des Gusseisens), U. Lohse. V. D. I. Zeit., vol. 71, no. 17, Apr. 1927, pp. 562-564. Difficulties in production of gray cast iron; different investigating methods; structure formation; discusses processes of Walter, Dürkopp-Luyken-Rein, Maschinenfabrik Esslingen, Diefenthäler-Lanz, Wüst, Emmel-Thyssen, Corsalli, Dechesne.

HALL-MARKS. Hall-Marks for Cast Iron. Foundry Trade Jl., vol. 35, no. 557, Apr. 21, 1927, pp. 330. Editorial suggesting that in case of novel developments process and not product should be labeled, and that classification of quality of product in terms of clearly defined and preferably national specifications, should considerably lessen bewilderment with which ordinary founder is at present liable to be assailed.

NICKEL IN. Nickel and Nickel-Chromium in Cast Iron, A. B. Everest. Brit. Cast Iron Research Assn.—Bul., no. 16, Apr. 1927, pp. 14-19. Review of published work; history of development of nickel cast iron; influence of nickel; special alloy cast iron; nickel-chromium cast iron. Bibliography.

RESEARCH LABORATORY. New Premises of the British Cast-Iron Research Association. Foundry Trade Jl., vol. 35, no. 556, Apr. 14, 1927, pp. 311-313, 3 figs. Chemical laboratory is equipped with usual range of apparatus for analysis, etc., and adjoining this is small machine shop containing lathe, drilling machine, saw, etc., mainly used for preparation of test pieces; hardness tests are made on Brinell system, and there is repeated-impact testing machine; research work in connection with heat-resisting irons; investigation of white-heart malleable cast iron.

RUNNERS, RISERS AND GATES. Runners, Risers and Gates, J. Butterworth. Foundry Trade Jl., vol. 35, no. 561, May 19, 1927, pp. 421-426, 6 figs. Runners, their economy and size; top and bottom running of medium and heavy castings; advantages of bottom running; taper and dummy risers; strain and French risers; open and closed risers.

SPECIFICATIONS. Report of Committee A-3 on Cast Iron. Am. Soc. for Testing Matls.—advance paper, no. 10, for mtg., June 20-24, 1927, 37 pp. 1 fig. Recommendations affecting standards; proposed revisions in standards; proposed methods of sampling and chemical analysis of pig and cast iron; sampling; methods of chemical analysis; determination of graphite.

STRUCTURAL COMPOSITION. Structural Composition of Cast Iron by Volume, J. L. Francis. Iron & Steel Industry & British Foundryman, vol. 1, no. 2, May 6, 1927, pp. 31-32. Shows how analytical results can be simply applied; structural composition by weight.

SULPHUR IN. The Influence of Sulphur in Cast Iron, J. E. Hurst. Foundry Trade Jl., vol. 35, nos. 556 and 559, Apr. 14 and May 19, 1927, pp. 314-316 and 419-420, 1 fig. It is generally considered that sulphur may exist in cast iron in form of two separate constituents, which are chemical compounds, sulphides of iron and manganese respectively; manganese sulphide; amount of manganese necessary to neutralize sulphur; influence of sulphur on mechanical properties.

WELDING. The Welding of Cast Iron, P. L. Roberts. Welding Jl., vol. 24, no. 282, Mar. 1927, pp. 70-76, 11 figs., and (discussion) no. 283, Apr. 1927, pp. 102-106. Both metallic and carbon arc, and oxyacetylene processes are used, each having field for which it is specially suitable; other processes such as resistance, butt and spot welding are neither successful nor suitable means for welding cast iron; thermit welding may be used with advantage in very few cases; metallurgical and mechanical properties of cast iron; expansion and contraction; free castings; semi-rigid and rigid castings.

CASTING

CENTRIFUGAL. Centrifugal Casting of Steel, L. Cammen. Am. Soc. Steel Treat.—Trans., vol. 11, no. 6, June 1927, pp. 915-949 and (discussion) 950-958. First part deals with centrifugal tube casting; its present and prospective field of application and limitations, particularly where centrifugal tube casting comes into competition with piercing process; second part is devoted to new art of centrifugal bar casting, affecting entire steel industry; its importance lies in its ability to produce metal of better quality at cost estimated to be from $3.50 to $8.50 per ton lower than present methods; mechanical and metallurgical features of process and machinery employed.

CENTRIFUGAL. Centrifugal Casting Processes, J. D. Capron. Am. Iron & Steel Inst.—advance paper, for mtg., May 20, 1927, 19 pp., 5 figs. Early developments; de Lavaud process of casting pipe; and its effect on iron; other centrifugal processes.

SHIP PROPELLER. Production of a Three-Blade Ship Propeller in Metal Wet-Casting Process (Herstellung einer dreiflügligen Schiffsschraube im Metall-Nassgussverfahren), M. Schied. Zeit. für die Gesamte Giessereipraxis, (Metal) vol. 48, no. 16, Apr. 17, 1927, pp. 65-66. Describes casting of a propeller weighing 130 kg., making extensive use of old material.

CASTINGS

DEFECTS. What Causes Common Defects in Castings? J. W. Bolton. Foundry, vol. 55, nos. 4 and 10, May 1 and May 15, 1927, pp. 357-360 and 403-405, 16 figs. Several typical casting defects have been selected, their appearance defined, their method of formation explained and possible remedies suggested.

CHROMIUM-NICKEL STEEL

HIGH-TEMPERATURE TESTS. Some Tests of Chromium-Nickel Steel at High Temperatures, R. S. MacPherran. Am. Soc.

for Testing Matls.—advance paper, no 33, for mtg., June 20-24, 1927, 2 pp., 1 fig. Tests to determine forging and upsetting properties of certain high chromium high nickel steel.

CHROMIUM STEEL

MOLYBDENUM AND SILICON, INFLUENCE OF. The Influence of Molybdenum and Silicon on Properties of a Stainless Chromium Steel (Ueber den Einfluss des Molybdäns und Siliziums auf die Eigenschaften eines nichtrostenden Chromstahls), W. Oertel and K. Würth. Stahl u. Eisen, vol. 47, no. 18, May 5, 1927, pp. 742-753, 18 figs. Results of tests carried out at Becker Steel Works, to determine properties of stainless steel to which small quatities of carbon molybdenum and silicon had been added; results showed that hardness of pure hardened chromium steel increased with increasing carbon content up to 0.30 per cent carbon; same is true for steel alloyed with molybdenum; steels alloyed with more than three per cent silicon show only slight increase in hardness.

COPPER

ANNEALING. The Annealing of Copper, N. R. Stansel. Gen. Elec. Rev., vol. 30, no. 5, May 1927, pp. 276-280, 9 figs. Changes in grain structure; recrystallization temperature; proper conditions for annealing furnaces; example of energy requirements.

ARSENICAL. Brittleness in Arsenical Copper, C. Blazey. Inst. of Metals—advance paper, no. 416, for mtg. Mar. 9-10, 1927, 15 pp., 7 figs. Type of brittleness in arsenical copper tubing developed by annealing in temperature range from 450 to about 650 deg. cent.; susceptibility to brittleness was inherent in "as-cast" billets from which tubes were made and no alteration in hot and cold working methods could eliminate it; after remelting, no trace of brittleness could be developed.

BISMUTH, EFFECT OF. Effect of Bismuth on Copper, D. Hanson and C. W. Ford. Inst. of Metals—advance paper, no. 418, for mtg. Mar. 9-10, 1927, 10 pp., 11 figs. Experiments made on copper containing up to 0.1 per cent. of bismuth, and effects of small quantities of bismuth on casting, hot and cold-rolling, mechanical properties, electrical conductivity, and microstructure of copper; experiments confirm great embrittling effect of bismuth, and indicate that when more than trace of bismuth alone is present in copper, working properties, particularly cold-working properties, are seriously affected; solid solubility of bismuth in copper.

ETCHING REAGENT. An Etching Reagent for Copper, B. W. Holman. Inst. of Metals—advance paper, no. 422, for mtg. Mar. 9-10, 1927, 1 p., 2 figs. Describes use of silver nitrate as an etching agent for copper, and suggests its utility in research work.

CORROSION

ELECTROLYTIC STUDIES. Principles of Electrolytic Studies on Corrosion, W. Blum and H. S. Rawdon. Am. Electrochem. Soc. —Advance Paper, no. 48, for mtg., Apr. 28-30, 1927, pp. 463-490, 23 figs. General principles of corrosion testing; electrolytic tests based on current only; relation of potentials to corrosion; factors involved in electrolytic test; proposed method is based on apparently sound electrochemical principles, and by means of it results have been obtained for a few metals and solutions, which appear to be consistent with general experience with these materials.

CUPOLAS

LINING REFRACTORIES. A Study of Cupola Lining Refractories, G. S. Schaller. Am. Foundrymen's Assn.—advance paper, no. 20, for mtg. June 6–10, 1927, 8 pp. Failure under load; spalling; slag corrosion.

TEMPERATURE RECORDERS. Correction of Cupola Operation by Means of Cupola Temperature Recorder, H. W. Dietert. Am. Foundrymen's Assn.—advance paper, no. 15, for mtg., June 6-10, 1927, 11 pp. 8 figs. Instrument consists of three parts, hood, thermo-couple and recorder; applicable to either continuous or intermittent flow of iron; iron temperature charts; causes of irregular temperatures; use on hand-charged cupola; effects of booster charge of coke.

CUTTING TOOLS

STRENGTH. The Strength of Cutting Tools. Mech. World, vol. 81, no. 2108, May 27, 1927, pp. 375-376, 4 figs. Ordinary single-edged tools of simple form practically depend for strength on cross-section of steel; many tools and cutters of normally sufficient strength are weakened by grinding too much clearance; sharp corners and angles are fruitful causes of fracture either in hardening and tempering or when cutting commences.

DIE CASTING

ALLOYS. Improved Die-Casting Alloy. Machy. (N. Y.), Vol. 33, no. 9, May 1927, p. 684. Die-cast test piece made by Superior Die Casting Co. from an improved zinc alloy similar to regular zinc alloy used for die-castings, but improved in manner that increases both tensile strength and twisting resistance.

DURALUMIN

HEAT TREATMENT, EFFECT OF. Drawing Qualities of Duralumin Sheet as Affected by Heat Treatment, R. J. Anderson. Am. Metal Market (Mag. Section), vol. 34, no. 95, May 17, 1927, pp. 5-7, 5 figs. As result of experiments carried out data have been obtained which indicate most suitable heat treatments to yield maximum depth of cup; data obtained may also be of interest in connection with specifications on drawing and forming qualities of light alloy sheet; effects of wide variety of heat treatments, both annealing and quenching, were examined by measurement of indentation (cupping) values and these data were correlated with tensile properties, hardness, and microstructure.

ELECTRIC FURNACES

ANNEALING. American Electric Annealing Furnaces and Their Economic Features (Amerikanische Elektroglühöfen und ihre Wirtschaftlichkeit), H. Nathusius. V. D. I. Zeit., vol. 71, no. 20, May 14, 1927, pp. 671-675, 14 figs. Discusses temperatures obtainable, and durability; design and operation of furnaces for castings, sheet metal, wire rolling, and portable furnaces with heat

storage; standard and rotary furnaces; discusses costs, time required for annealing, and uniformity of heating; influence of electric annealing.

AUTOMATIC. The Automatic Electric Furnace—Its Uses and Possibilities, H. F. Wood. Am. Society Steel Treat.—Trans., vol. 11, no. 6, June 1927, pp. 975-985, 9 figs. Equipment consists of two rotary-hearth electric furnaces, one to be used for hardening and other for tempering (drawing), with automatic charging and discharging devices on each furnace, automatic quenching mechanism, and transfer conveyors; hearth is all structural steel construction. With railroad rails running on drop-forged and heat treated rollers, roller bearings being used throughout to reduce friction to minimum; advantages are that it makes possible location of heat treating operations with other production operations; 100 per cent individual handling of product in heat-treating operation resulting in exact duplication of treatment on each individual part; complete elimination of direct labor on heat treating operation; maximum production per sq. ft. of floor space and maximum flexibility.

HIGH-FREQUENCY. Alloys of Precious Metals and the High Frequency Induction Furnace, R. V. Williams. Metal Industry (N. Y.), vol. 25, nos. 4 and 5, Apr. and May, 1927, pp. 141-143, and 188-190, 12 figs. Manufacturing dental alloys from waste materials by aid of this type of furnace.

INTERNALLY HEATED. Internally-Heated Furnaces. Elec. Rev., vol. 100, no. 2581, May 13, 1927, pp. 748-749, 4 figs. Recent development in total enclosure of heating elements of resistance furnaces by means of specially shaped bricks which are built up to form furnace lining, providing adequate support and uniform heating.

TRANSFORMERS FOR. Loading Capacity, Design and Dimensions of Transformers for Steel Arc Furnaces (Belastungsfähigeit, Bauart und Bemessung der Transformatoren für Lichtbogen-Elektrostahlöfen), S. Kriz. Stahl u. Eisen, vol. 47, no. 16, Apr. 21, 1927, pp. 653-658, 8 figs. Factors affecting design and dimension; present diagram showing most economical transformer dimensions for furnaces of different sizes.

ELECTRIC WELDING, ARC

POWER SHOVELS. Sees Economic Advantages in Welding of Power Shovel Parts. Iron Trade Rev., vol. 80, no. 19, May 12, 1927, pp. 1216-1217, 5 figs. Application of electric arc welding in construction of power shovel.

REPLACING CASTINGS BY. Replacing Castings by Welded Steel Parts, J. F. Lincoln. Am. Welding Soc.—Jl., vol. 6, no. 4, Apr. 1927, pp. 33-41, 7 figs. Considers problems involved.

STRUCTURAL. Modern Structural Industry Demands a Knowledge of Arc-Welding, C. J. Holslag. Am. Welding Soc.—Jl., vol. 6, no. 4, Apr. 1927, pp. 82-88, 4 figs. Deals primarily with arc welding structural work.

STRUCTURAL STEEL. Electric Arc Structural Steel, F. A. Marsh. Welding Engr., vol. 12, no. 5, May 1927, pp. 29-31, 3 figs. Through use of welded joints many steel structures can be made stronger with less material and less labor.

STRUCTURAL STEEL. Electric Arc Welding, A. M. Candy. Neb. Blue Print, vol. 26, no. 5, Mar. 1927, pp. 7-10, 4 figs. data and conclusions drawn from recent tests of electric arc-welded structural-steel joints.

ELECTRIC WELDING, RESISTANCE

SEAMS. Resistance Line Welding, H. W. Tobey. Am. Welding Soc.—Jl., vol. 6, no. 4, Apr. 1927, pp. 74-81, 7 figs. In case of seam, or line welding, one of electrodes takes form of wheel, while other may be either roll or bar; width and strength of weld depend upon current, pressure and speed adjustments as well as upon size and shape and character of electrodes and metal being welded; examples of specific application of line welding; describes several types of machines in regular operation.

ELECTRIC WIRING

COPPER. Hard-drawn Copper Conductors. Engineer, vol. 143, no. 3720, Apr. 29, 1927, p. 463. As cast electrolytically refined copper has nothing but its high conductivity to recommend it; resistivity of pure annealed copper; elastic limit of hard-drawn copper wire; value of British standard specification for this material.

FERROALLOYS

SPECIFICATIONS. Report of Committee A-9 on Ferro-Alloys. Am. Soc. Testing Matls.—advance paper, no. 16, for mtg., June 20-24, 2 pp.

FERRONICKELS

INTERNAL FRICTION. Anomalous Internal Friction of Reversible Ferronickels (Anomalie du frottement interne des ferronickels reversibles), P. Chevenard and M. Le Chatelier. Académie des Sciences—Comptes Rendus, vol. 184, no. 7, Feb. 14, 1927, pp. 378-380, 1 fig. Three-dimensional diagram as constructed to show variation of decrease in reversible ferronickels in iron-nickel alloys as function of temperature and of nickel content; decrease corresponds to internal friction of ferronickels; internal friction is sensitive to secondary influences, such as state of oxidation and thermal and mechanical histories of sample. See brief translated abstract in Chem. & Industry, vol. 46, no. 16, Apr. 22, 1927, p. 279.

FORGING

ALUMINUM ALLOYS. The Forging of Aluminum Alloys, J. Strauss. Forging—Stamping—Heat Treating, vol. 13, no. 5, May 1927, pp. 162-169, 4 figs. Methods for melting, forging and heat treating alloys of aluminum; preparation of ingots; properties of alloys; alloys of copper. Bibliography.

DIE INSERTS. Economical Possibilities of Die Inserts, G. H. Koskey. Forging—Stamping—Heat Treating, vol. 13, no. 5, May 1927, pp. 186-187. Discourse on forge shop management with some positive expressions concerning value of die inserts.

MACHINE VS. HAND. Machine versus Hand Forging. Ry. Mech. Engr., vol. 101, no. 5, May 1927, pp. 298-301, 8 figs. Comparison of relative costs of nine typical forging machine operations at C. & N. W. Shops.

FOUNDING

SCIENCE IN. The Role of Science in Founding (Le Role de la Science en Fonderie), Rabozee. Fonderie Moderne, vol. 21, Apr. 25, 1927, pp. 73-78, 14 figs. Mechanical tests; research; chemical and thermal analysis; metallography; it is author's opinion that progress can only be effected by coöperation between industry and science.

RAW MATERIALS. An Informal Discussion on Foundry Raw Materials. Foundry Trade Jl., vol. 35, no. 556, Apr. 14, 1927, pp. 317-318. Review of iron founders' raw materials; use of hematite extending; use of fluorspar; cold blast; core-oil adulteration; moisture in coke; sulphur content and hardness; how high sulphur can operate.

FURNACES, HEAT-TREATING

DESIGN. Heat Treating Furnaces. Iron Trade Rev., vol. 80, no. 19, May 12, 1927, pp. 1218-1220, 2 figs. Design, construction and function.

HARDNESS

INDENTATION. A Further Investigation of the Indentation Hardness of Metals, K. Honda and K. Takahasi. Iron & Steel Inst. —advance paper, no. 11, May 1927, 11 pp., 5 figs. Shows by experiments necessity for using new number for Brinell hardness, measured while load is on.

HEATING, ELECTRIC

METALLIC MATERIALS FOR. Report of Committee B-4 on Metallic Materials for Electrical Heating. Am. Soc. Testing Matls. —advance paper, no. 20, for mtg., June 20-24, 22 pp., 2 figs. Proposed tentative method of test for change of resistance with temperature of metallic materials for electrical heating; methods of chemical analysis for metallic materials; determination of chromium by persulphate method and iron by Cupferron method; determination of manganese; determination of carbon by volumetric method; determination of insoluble residue.

IRON

ALPHA, CARBON SOLUBILITY IN. Notes on Pseudo-Twinning in Ferrite, and on the Solubility of Carbon in Alpha-Iron at the A_1 Point, S. Tamura. Iron & Steel Inst.— advance paper, no. 15, May 1927, 7 pp., 13 figs. As has been demonstrated annealing twins in metals are structurally in very stable state; but formation of this kind of twinning is closely related to atomic structure of metal; with face-center cubic lattice arrangement, as in case of copper twinning takes place with relative ease during atomic rearrangement; however, metals which, like ferrite, crystallize in body-centered cubic lattice seldom, if ever, produce this structure; therefore, it is not possible to state definitely that structures found in ferrite, are true annealing twins; at present it is preferable to call them "pseudo-twins."

FLUORINE, DESULPHURIZING ACTION OF. The Desulphurizing Action on Molten Iron of Some Chemical Components Containing Fluorine, E. Wilke and H. Buchholz. Foundry Trade Jl., vol. 35, no. 556, Apr. 14, 1927, p. 322, 1 fig. Study of effect of some fluor compounds on molten iron with respect to sulphur content. Translated abstract from Stahl u. Eisen, Dec. 23, 1926.

INDUSTRIAL APPLICATION. Pure Iron in its Industrial Applications, L. P. Sidney. Iron & Steel Industry & British Foundryman, vol. 1, no. 2, May 6, 1927, pp. 41-43. Homogeneity and corrosion; commercially pure iron; ingot iron; importance of homogeneous base in tinning, galvanizing and enameling; reliability of homogeneous material.

SULPHUR IN. Sulphur in Iron and Steel (Sur le Probleme du Soufre Contenu dans la Fonte et dans l'Acier), J. Ciaohina. Chimie & Industrie, vol. 17, no. 3, Mar. 1927, pp. 333-384. Free sulphur is determined by passing CO_2 through Corleiss flask in which sample is being dissolved in concentrated hydrochloric acid; determination of sulphur by combustion gives higher results than hydrogen sulphide method. See brief translated abstract in Chem. & Industry, vol. 46, no. 19, May 13, 1927, p. 335.

IRON ALLOYS

IRON-PHOSPHORUS. The Constitution of Alloys of Iron and Phosphorus, J. L. Haughton. Iron & Steel Inst.—advance paper, no. 10, for mtg., May 1927, 18 pp., 35 figs. Review of earlier investigations; present research has been undertaken with object of determining constitution of these alloys when materials of high purity and modern methods of study are employed.

RESEARCH. Alloys of Iron Research, Parts V., VI., and VII., Iron & Steel Inst.— advance paper, no. 17, May 1927, 52 pp., 33 figs. Contains introduction, by Walter Rosenhain and three parts, as follows: Preparation of Pure Chromium, F. Adcock; Preparation of Pure Manganese, M. L. V. Gayler, Preparation of High-Purity Silicon, N. P. Tucker; papers represent systematic study of alloys of iron with certain other elements.

IRON AND STEEL

LOCOMOTIVE. Metallurgy of Locomotive Iron and Steel, F. Williams. Ry. Mech. Eng., vol. 101, no. 5, May 1927, pp. 264-266, 18 figs. With reference to heat treating and physical properties desirable for locomotive use; character of alloy steels; characteristics of spring steel.

TESTING. Making and Heat-Treating Iron and Steel, R. Job. Can. Machy., vol. 37, no. 20, May 19, 1927, pp. 20-21. Outlines manner in which testing of iron and steel is carried out and importance of tests to industry.

IRON CASTINGS

BLAST-FURNACE. Blast-Furnace Metal Castings. Foundry Trade Jl., vol. 35, no. 557, Apr. 21, 1927, pp. 343-344. It may be considered that use of direct blast-furnace metal was very earliest method adopted of supplying molten metal to iron foundry; exclusion from British specifications; extensive foreign employment; traditional prejudice; direct metal and sulphur content; other grounds of objection to use of direct metal; incorporation of receiver desirable.

BLOWHOLES. The Problem of Blowholes, Iron & Steel Industry & Brit. Foundryman,

vol. 1, no. 1, April 1, 1927, pp. 16-17. Simple explanation of their cause and suggestions for minimizing their injurious effect.

COLUMNS. Cast-Iron Columns, W. J. May. Mech. World, vol. 81, no. 2104, Apr. 29, 1927, p. 301. Method of casting has more to do with actual strength of column than is often supposed; the longer the casting the greater the difficulty in securing absolute soundness in metal; in case of hollow columns chief difficulties arise owing to cores rising in center, causing unevenness in thickness of walls.

DEFECTIVE. Analysis of Four Hundred Tons of Defective Castings, J. M. Haley. Am. Foundrymen's Assn.—advance paper, no. 2, for mtg., June 6-10, 1927, 10 pp., 2 figs. Study of conditions in gray iron foundry, average production of which approximates 80 tons per day; analysis of defective castings which varied in weight from 4 ounces to 6000 lb.; defects are classified and methods of controlling future production with an elimination of these defects discussed.

LARGE. The Manufacture of Large Iron Castings, H. Fabre. Foundry Trade Jl., vol. 35, no. 559, May 5, 1927, pp. 377-380, 4 figs. Elucidates certain points which appear to be of special importance; organization and shops; transport equipment; plant and materials; patternmaking; molding; raw materials; gaging of runners; shrinkage; defects; scabbed castings.

SNAGGING. Notes on Snagging. Iron & Steel of Canada, vol. 10, no. 4, Apr. 1927, pp. 107-109, 4 figs. Snagging generally means rapid removal of large quantities of metal from rough castings as they come from molds; it is a process which because of its high production and efficiency has practically eliminated chipping as standard method for cleaning castings; large quantities of wheels are used, and for this reason factors affecting choice and use of wheels should be clearly understood.

IRON, PIG

FOUNDRY. The Evaluation of Foundry Pig Iron, R. Moldenke. Am. Foundrymen's Assn.—advance paper, no. 5, for mtg., June 6-10, 1927, 6 pp. Early history of agitation for some standard method of evaluating quality of pig iron in addition to chemical analysis; need is stated to be largely caused by practice of blast furnaces operating using cast-iron scrap additions to furnace burden; discusses factors for improving quality of iron in castings by such methods as superheating.

LEAD ALLOYS

LEAD-TIN. Note on the Crystallization of the Lead-Tin Eutectic, F. Hargreaves. Inst. of Metals—advance paper, no. 422, for mtg., Mar. 9-10, 1927, 2 pp., 3 figs. Straining and etching methods applied to 30-lb. ingot of lead-tin eutectic show exterior to possess largest crystal size with absence of distinct colonies; middle consists of much smaller crystal units in form of distinct colonies of coarser eutectic structure.

MAGNESIUM ALLOYS

MAGNESIUM-COPPER. Note on the Magnesium-Rich Magnesium-Copper Alloys, M. Hansen. Inst. of Metals—advance paper, no. 428, for mtg., Mar. 9-10, 1927, 8 pp., 14 figs. Results of investigation of solubility of copper in solid magnesium and mechanical properties of some magnesium-rich magnesium-copper alloys; indication of phase boundary of solid solution of magnesium with copper has been obtained; microstructure of quenched and slowly cooled alloys; quenched alloys show no perceptible hardening by aging; mechanical properties of extruded material both with and without heat treatment.

MALLEABLE CASTINGS

SPECIFICATIONS. Report of Committee A-7 on Malleable Castings, W. P. Putnam. Am. Soc. Testing Materials—advance paper, no. 14, for mtg., June 20-24, 1927, 1 p.

MANGANESE

PROPERTIES. The Metal Manganese and Its Properties, R. Hadfield. Iron & Steel Inst.—advance paper, no. 7, for mtg., May 1927, 72 pp., 8 figs. General historical account of metal manganese and uses to which it has been applied; shows interesting way in which production and use of ferromanganese was brought about, and important part played in its development by Great Britain; present world position as regards resources of manganese ores, more particularly from British point of view. See also abstract in Engineering, vol. 123, no. 3200, May 13, 1927, pp. 576-578.

MANGANESE STEEL

WELDING. To Weld Manganese Steel. Iron & Steel of Canada, vol. 10, no. 4, Apr. 1927, p. 115. Preheating and heat treatment after welding are necessary for work on this metal.

METALLURGY

ENGINEERING SERVICE. Services of Metallurgy to Engineering, H. C. H. Carpenter. Foundry Trade Jl., vol. 35, no. 561, May 19, 1927, pp. 417-418. Abstract of James Forrest Lecture; electric-furnace practice; pearlitic cast iron; Sandberg process of rail treatment.

METALS

COLOR MANIFESTATIONS. Judges Temperatures Visually, R. R. Clarke. Foundry, vol. 55, no. 10, May 15, 1927, pp. 396-397, 1 fig. Discusses a few common metals and alloys with regard to their color manifestation; fluidity factor; action of metal in sprues.

CORROSION. The Intercrystalline Corrosion of Metals, H. S. Rawdon. Indus. & Eng. Chem., vol. 19, no. 5, May 1927, pp. 613-619, 15 figs. Intercrystalline corrosion as related to microstructural features of metal; combined effect of stress and corrosion in producing intercrystalline brittleness.

STRESSES IN. Some Experiments on The Effect of Repeated Stresses on Materials, F. C. Lea. Instn. Aeronautical Engrs.—Jl., vol. 1, no. 5, May 1927, pp. 7-41 and (discussion) 41-46, 27 figs. Machines used to determine fatigue ranges of materials; it is concluded that for all practical purposes most materials have a real fatigue range; in case of carbon and alloy steels used for many parts of airplane engines when heat treated so as to give varying ultimate stresses, total fatigue

range for equal and opposite stress varies from 0.8 to 1 times the breaking strength but for other materials it may be less than one half breaking strength; cold-worked materials like carbon steel tubes and brass tubes have their fatigue ranges increased by heat treatment; key to failure of materials under repeated stress has not been found.

MICROSCOPES

METALLURGICAL. The Metallurgical Microscope, G. Pirk. Gen. Elec. Rev., vol. 30, no. 5, May 1927, pp. 264-273, 14 figs. Effect of object structure on light waves; limits of resolving power; achromats and apochromats; oculars or eyepieces; illumination and illuminants; plane glass vs. prism illuminator.

MOLDS

PERMANENT. The Holley Permanent Mould Process. Foundry Trade Jl., vol. 35, no. 559, May 5, 1927, pp. 381-382 and (discussion) 382-384. Review of J. W. Hinchley's paper on permanent molding machines for cast iron, in which he described plant used by Holley Carburetor Co. of Detroit, for making of small castings of cast iron in permanent molds, mounted on rotating platform.

MONEL METAL

SPRINGS. Monel Metal, H. P. Troendly. Neb. Blue Print, vol. 26, no. 5, Mar. 1927, pp. 14-15 and 25. Important factors of spring design, and comparison of qualities of monel metal with various materials.

NICKEL

COLD-WORKED. Correlation of Magnetic Properties with Mechanical Hardness in Cold-Worked Metals, S. R. Williams. Am. Soc. Steel Treat.—Trans., vol. 11, no. 6, June 1927, pp. 885-898 and (discussion) 898 and 1041. Change in length due to magnetic field, (Joule magnetostrictive effect), coercive force, residual magnetism, hysteresis loss per cycle and electrical conductivity are studied in set of nickel strips which have 11 deg. of hardness obtained by cold rolling; with all these effects measured on same set of nickel strips it is possible to study results with view to correlation and with possibility that some light may be cast upon hardness; various physical properties are modified by hardness produced by rolling, similar in many ways, to that produced by heating in case of steel; it would appear, therefore, that hardness produced by these two methods have great deal in common as viewed from magnetic viewpoint.

NONFERROUS METALS

CORROSION FATIGUE. Corrosion-Fatigue of Non-Ferrous Metals, D. J. AcAdam, Jr. Am. Soc. Testing Matls.—advance paper, no. 36, for mtg., June 20-24, 23 pp., 6 figs. Résumé of previous work, and outline of investigation; corrosion fatigue of nickel-copper alloy; effects of cold working on corrosion-fatigue limits; relationship between chemical composition and corrosion-fatigue limits of nickel-copper alloys; corrosion fatigue of aluminum alloys; tentative hypotheses are discussed under following headings: intrinsic corrosion-fatigue limits; secondary influences affecting corrosion-fatigue limit, relationship between fatigue and corrosion fatigue.

METALLURGY. Recent Progress in Non-Ferrous Metallurgy, W. H. Bassett. Min. & Met., vol. 8, no. 245, May 1927, pp. 214-218. Deoxidizing of copper; effect of impurities in copper; copper-rich brass; silicon for hardening; cupro-nickel; high-strength conductors.

OPEN-HEARTH FURNACES

CHEQUERWORK. Chequerwork of O. H. Furnaces, Iron & Coal Trades Rev., vol. 114, no. 3086, Apr. 22, 1927, pp. 644-645, 5 figs. Review of article in Stahl u. Eisen by E. Herzog in which he pays special attention to chequerwork; deals first with effect of total area of heating surface and heat-storage capacity of chequerwork per unit of heating surface; factor of importance in considering storage capacity of chequerwork in accumulating and dispersing processes in chequer bricks.

DEVELOPMENTS. Open-Hearth Furnace, Past and Present, C. S. Nugent. Blast Furnace & Steel Plant, vol. 15, no. 5, May 1927, pp. 225-226. Practical furnace operator reviews development to present day; manner of constructing modern furnace; operating features.

RADIATION. Tests to Determine Degrees of Radiation in Open-Hearth Furnaces (Versuche zur Feststellung von Strahlungsgrössen in Siemens-Martinöfen), V. Polak. Zeit. für Technische Physik, vol. 8, no. 2, 1927, pp. 71-74, 5 figs. Importance of radiation of flue gases in heat transmission in open-hearth furnaces; nature of gas radiation; results of radiation measurements.

OXYACETYLENE WELDING

ALUMINUM SHEET. Welding Pure Aluminum Sheet. Oxy-Acetylene Tips, vol. 5, no. 10, May 1927, pp. 188-191, 10 figs. Wide use of this material furnishes opportunities for fabricating special equipment.

APPLICATIONS. A Resume of the Fields of Application of Oxy-Acetylene Welding and Cutting, D. S. Lloyd. Iron & Steel of Canada, vol. 10, no. 4, Apr. 1927, pp. 102-106, 11 figs. Describes only those applications of process that have been very successful in reducing costs in commercial field.

CHEMICAL PLANTS. Oxyacetylene Welding in Chemical Plant Construction, G. O. Carter and W. B. Miller. Indus. & Eng. Chem., vol. 19, no. 6, June 1927, pp. 695-697, 4 figs. Study of construction materials necessary; welding operation; advantages of welded joints.

STEAM PIPE LINES. Gas Welding Versus Flange Joints for Steam Lines, G. O. Carter. Power, vol. 65, no. 22, May 31, 1927, pp. 823-824. Arguments for replacement of flange joints by welding; ability to stand thrust and pull of pipe bends; taking care of expansion and contraction; importance of procedure control; insulation problem; saving money on tunnel lines; demand for flangeless valves and fittings.

PIPE, CAST-IRON

AMERICAN AND FRENCH MANUFACTURE. Comparative Tests of Six-Inch Cast-

Iron Pipes of American and French Manufacture, S. N. Petrenko. U. S. Bur. Standards —Tech. papers, no. 336, Mar. 1, 1927, pp. 231-254, 9 figs. Pipes were of "bell and spigot" type and were cast in sand molds; tests, which included hardness, transverse, ring, shear, impact, and hydrostatic tests, shows that strength of French pipe lay within range of variation of American pipe; French pipe was also characterized by greater hardness, low impact values, and higher content of phosphorus (about 1.85 per cent) than in American pipe.

AMERICAN AND FRENCH MANUFACTURE. Results of Tests on Cast-Iron Pipe (Resultats d'Essais sur des Tuyaux en Fonte). Fonderie Moderne, vol. 21, Apr. 25, 1927, pp. 86-88, 2 figs. Comparison of French and American pipe made by U. S. Bureau of Standards; new method of test, by M. A. Belestre.

BRONZE WELDED. Temperature and Bending Strains in Bronze Welded C. I. Pipe Lines, E. Hering, F. G. Outcalt and T. W. Greene. Gas Age-Rec., vol. 59, no. 19, May 7, 1927, pp. 659-660, 3 figs. Necessity of careful laying procedure and desirability of expansion joints at 100-ft intervals.

SOIL CORROSION. Bureau of Standards Soil Corrosion Investigation, K. H. Logan. Am. Foundrymen's Assn.—advance paper, no. 10, for mtg., June 6-10, 1927, 39 pp. 21 figs. Second progress report on unprotected pipe; investigation of relation of soils to corrosion, primary purpose of which was to ascertain extent to which soil action might account for observed deterioration of buried pipes.

REFRACTORIES

FACTORS AFFECTING. Factors Affecting Refractories. Foundry, vol. 55, no. 10, May 15, 1927, supp. plate. Utilities of refractories; resistance to destruction. Foundry data sheet.

GAS PERMEABILITY. The Gas Permeability of Refractory Brick Used in Metallurgical Furnaces, F. A. Wickerham. Am. Iron & Steel Inst.—advance paper, for mtg., May 20, 1927, 25 pp., 5 figs. Investigation was made to try to imitate in a practical way what might be expected of bricks in actual service.

OPEN-HEARTH. Factors Affecting Open-Hearth Refractories, B. M. Larsen and A. Grodner. Blast Furnace & Steel Plant, vol. 15, no. 5, May 1927, pp. 217-220, 12 figs. Analysis of heat transfer and temperature, as they affect refractories in melting chamber; water cooling and wall insulation play prominent part.

SPECIFICATIONS. Report of Committee C-8 on Refractories. Am. Soc. Testing Matls. —advance paper, no. 48, for mtg., June 20-24, 24 pp. Proposed tentative specifications for clay firebrick for malleable furnaces with removable bungs and for annealing ovens; and for stationary boiler service and marine-boiler service; proposed tentative definitions of terms relating to refractories.

ROLLING MILLS

BLOOMING MILLS. The Design of 3-High Blooming-Mills Taking Care of Rolls into Consideration (Die Kalibrierung der Vorwalztrios unter Berücksichtigung guter Walzenausnutzung), H. Cramer. Stahl u. Eisen, vol. 47, no. 18, May 5, 1927, pp. 737-742, 9 figs. Discusses possibility of better utilization of rolls on a 3-high blooming-mill.

COLD STRIP ROLLING. Cold-Rolled Strip Steel, T. Swinden and G. R. Bolsover. Iron & Coal Trades Rev., vol. 114, no. 2088, May 6, 1927, pp. 724-727, 18 figs. Effect of progressive cold rolling on steels of different composition, and on steels of similar composition, but in different conditions as regards heat treatment prior to cold rolling; effect of heat treatment on some of above steels after they had received varying amounts of cold rolling. Abstract of paper read before Iron & Steel Inst.

DYNAMIC PROBLEMS. Dynamic Conditions in Connection with Rolling (Nagra dynamiska förhallanden vid valsning), S. Ekelund. Jernkontorets Annaler, no. 2, 1927, pp. 39-106, 16 figs. Author seeks to establish formulas for power requirements and other conditions in rolling; presents theoretical calculations.

ELECTRIC DRIVE. Electric Rolling-Mill Drives. Elec. World, vol. 89, no. 20, May 14, 1927, pp. 1014-1016, 4 figs. Where d. c. and a. c. motors are most desirable; recent combinations and methods of securing flexible control.

FORD PLANT. The Steel Mill at the Ford Plant, T. Harvey. Blast Furnace & Steel Plant, vol. 15, no. 5, May 1927, pp. 212-216, 2 figs. Merchant and blooming-mill motors and control; projected developments and equipment.

GUIDES, CASTINGS FOR. Hypo-eutectic Castings for Rolling-Mill Guides (Fontes hypo-eutectiques pour guides de laminoirs), E. Dechert. Fonderie Moderne, vol. 21, Apr. 10, 1927, pp. 49-51, 4 figs. Results of tests with two types of castings to determine which composition is best for wire and rod mill guides.

MAIN-DRIVE REGULATION. Speed Regulation of the Main Roll Drives, L. A. Umansky. Iron & Steel Engr., vol. 4, no. 5, May 1927, pp. 207-218, 19 figs. Deals with following problems: (1) how close a speed regulation need be provided for sectionalized main roll drives and what determines required regulation? (2) What speed regulation may be obtained with electrical machines as are used for such drives? (3) Is this speed regulation sufficient to meet mill requirements? if not, in what cases is is not sufficient? (4) If inherent speed regulation is not sufficient for mill requirements, can any remedy be applied to still further improve regulation, and what is remedy?

PILGER. The Pilger Tube Mill of the Pittsburgh Steel Products Company, W. C. Sutherland. Am. Iron & Steel Inst.—advance paper, for mtg., May 20, 1927, 15 pp., 12 figs. Mannesmann Pilger mill installation of Pittsburgh Steel Products Co. is complete in every detail and is a tube mill capable of producing tubes from 6 to 12 in. in diameter by 46 ft. long or even much longer for special cases; it starts with charging a cast round ingot in heating furnace and loads out a finished, threaded and coupled tube on shipping track, having produced all parts and performed all operation

to finish all parts that enter into make-up of finished product; heaviest tubes produced to date were 11 3/4 in. outside diameter by 32 ft. long with 1 1/8 in. wall, each of which weighed approximately 4400 lb.; nominal capacity of mill is 300 tons per day.

STRIP MILLS. Laclede Hot Rolled Strip Mill. Iron Age, vol. 119, no. 21, May 26, 1927, pp. 1525-1527, 4 figs. Electrical features of new plant at Alton, Ill., for producing strips up to 12 in. in width and down to 0.035 in. in thickness.

STRIP MILLS. Roll Thin Strip Steel on 4-High Mill, F. B. Pletcher. Iron Trade Rev., vol. 80, no. 21, May 26, 1927, pp. 1329-1331, 3 figs. Second four-high strip mill, placed in operation in St. Louis district.

WELDING AND CUTTING IN. The Maintenance of Rolling Mill Machinery. Oxy-Acetylene Tips, vol. 5, no. 10, May 1927, pp. 194-204, 22 figs. Breakdown delays are minimized when welding and cutting flames are freely used; wabbler repairs; welding aluminum bronze; pinion repairs.

ROLLS

CHILLED. Chilled Roll Making. Foundry Trade Jl., vol. 35, nos. 555 and 557, Apr. 7, and 21, 1927, pp. 293-294 and 335-336. Apr. 7: Broader metallurgical aspects; current practice; nature of charge; furnaces; working charge; casting temperature. Apr. 21: Future prospects; factors affecting chill; economies to be effected; gas firing; pulverized fuel; suggested duplex process.

SEMI-STEEL

ADVANTAGES OF. Controversy on Semi-Steel (Controverse sur la Fonte Aciérée), A. Legrand. Fonderie Moderne, Vol. 21, Apr. 10, 1927, pp. 53-54. Author replies to criticisms of his article published in Oct. 26 issue of same journal.

SHEET METAL

ANNEALING, INFLUENCE OF. Influence of Annealing Temperature on the Properties of Mild-Steel Sheets, C. A. Edwards and J. C. Jones. Iron and Coal Trades Rev., vol. 114, no. 2088, May 6, 1927, pp. 719-724. Determination of influence of varying annealing temperatures upon values obtained in Erichsen test with sheets 0.33, 0.4, 0.5, 0.8, and 1.25 mm. thick; effects of annealing temperatures on tensile properties; parallel with direction of rolling in sheet mill, and at right angles to this direction of rolling; tensile tests made on thick steel sheets. Paper read before Iron & Steel Inst.

TENSILE PROPERTIES. Methods for Determining the Tensile Properties of Thin Sheet Metals, R. L. Templin. Am. Soc. for Testing Matls.—advance paper, no. 31, for mtg., June 20-24, 1927, 16 pp., 9 figs. Deals with metals varying in thickness from 0.005 to 0.250 in., inclusive; methods discussed have been used for number of years in laboratories of Aluminum Co. of America, not only for aluminum and magnesium and their alloys but also for numerous other sheet metals, both ferrous and non-ferrous; economical methods for machining of tension test specimens, application of gage marks and measuring of specimen dimensions.

EXTENSION TESTS. Tension Test Specimens for Sheet Steel, J. T. Nichols, E. S. Taylerson and J. C. Whetzel. Am. Soc. for Testing Matls.—advance paper, no. 30, for mtg., June 20-24, 1927, 9 pp., 6 figs. Series of tests carried on sheet steel of various grades and thicknesses, making use of seven different test specimens and also varying radius of fillet and end width; results show that yield point and tensile strength are only slightly affected by shape of specimen; for material of same grade, elongation is definite function of size of gage section.

SPRINGS

HAIRSPRINGS FOR INSTRUMENTS. The Manufacture and Properties of Hairsprings, H. Moore and S. Beckinsale. Inst. of Metals—advance paper, no. 424, for mtg., Mar. 9-10, 1927, 9 pp.; also abstract in Engineering, vol. 123, no. 3195, Apr. 8, 1927, pp. 439-440. Investigation at Research Department, Woolwich, into manufacture and properties of several types of hairsprings for instruments; related work, mainly of metallurgical nature, was also carried out on small springs used for other purposes; functions, and essential properties of hairsprings and control springs; respective merits and disadvantages of steels, ferrous alloys, and non-ferrous alloys; use of low-temperature heat treatments to restore elasticity, after cold working; steel hairsprings are subject to corrosion, but Elinvar is highly resistant; manufacture of phosphor-bronze and other hairsprings.

HEAT TREATMENT. The C. N. R. Installs Spring Treating Plant. Ry. Mech. Engr., vol. 101, no. 6, June 1927, pp. 341-344, 6 figs. Electric furnace and salt bath for heating and drawing, at Stratford, Ont., shops, are pyrometer controlled.

STEEL

AUSTENITIC STRUCTURE. The Decomposition of the Structure in Steels, O. E. Harder and R. L. Dowdell. Am. Soc. Steel Treat.—Trans., vol. 11, no. 6, June 1927, pp. 959-974. Application of powder method of X-ray analysis to study of changes in structure of steels during heat treatment; steels have been examined in three conditions: 1, as quenched; 2, after submersion in liquid oxygen; 3, after various tempering treatments; results show that on submersion in liquid oxygen there is no increase in intensity of alpha-lines expected from amount of martensite formed in larger specimens in same treatments; they also indicate that certain transformations which produce martensitic structure give alpha particles which are too small to be recorded in crystallogram; position of carbon in space lattice of steels investigated.

HARDENABILITY. A Study of the Hardenability of Steel, J. D. Gat. Forging—Stamping—Heat Treating, vol. 13, no. 5, May 1927, pp. 188-191 and 195, 6 figs. Over emphasis of certain "indices of abnormality" results in confusion; grain size not determining factor; previous heat treatment of no influence.

HEAT-RESISTING. Heat-Resisting Steels, W. H. Hatfield. Iron & Steel Inst.—advance paper, no. 9, for mtg., May 1927, 26 pp., 1 fig. Account of investigations carried out in Brown-Firth Research Laboratories; behaviour of steels of various compositions, produced by alloying them in different proportions; protective action of chromium is generally confirmed; influence of silicon and tungsten in further increasing resistance would appear to be fully established; influence of industrial gases. See also abstract in Iron & Coal Trades Rev., vol. 114, no. 2088, May 6, 1927, pp. 722-724.

INGOTS, STRUCTURE OF. Physical and Chemical Structure of Ingots, J. D. Gat. Blast Furnace & Steel Plant, vol. 15, no. 5, May 1927, pp. 207-211, 9 figs. Defects in ingots such as piping, segregation, liquation, banding and porosity, considered from metallurgical viewpoint; their formation studied.

PICKLING. Some Notes on the Pickling of Steel, W. H. Ibbotson. Indus. Chemist, vol. 3, no. 27, Apr. 1927, pp. 147-148. Pickling by sulphuric acid; process using hydrochloric acid; review of salient points.

SOLDER PENETRATION. The Penetration of Mild Steel by Brazing Solder and Other Metals, R. Genders. Inst. of Metals—advance paper, no. 430, for mtg., Mar. 9-10, 1927, 7 pp., 8 figs. Cracking of mild steel under slight stress when heated and wetted with brazing solder is due to rapid intercrystalline penetration of steel by brass; copper behaves similarly to brass, but zinc, tin, and lead-tin solder have no perceptible action; behavior of mild steel in comparison with that of other metals when stressed and exposed to corrosive media.

SPECIFICATIONS. Report of Committee A-1 on Steel. Am. Soc. for Testing Matls.—advance paper, no. 8, for mtg., June 20-24, 1927, 43 pp., 2 figs. Recommendations affecting standards and tentative standards; report of subcommittee on size and location of test coupons on steel castings; proposed revisions in standards; specifications for carbon-steel castings for valves, flanges and fittings for high-temperature service; lap-welded and seamless steel pipe for high-temperature service; structural steel for cars and locomotives; marine-boiler steel plates; alloy tool steel.

STANDARDS FOR GEARS. Proposed Standards of Steel for Gears. Can. Machy., vol. 37, no. 19, May 12, 1927, p. 20. Presenting for criticism and comment of Subcommittee on Gear Materials, sponsored by American Gear Manufacturers' Association and A. S. M. E.

SULPHUR IN. Determination of Sulphur in Steel Grindings (Verfahren zum Nachweis von Schwefel in Stahlschliffen), H. J. van Royen and E. Ammermann. Stahl u. Eisen, vol. 47, no. 15, Apr. 14, 1927, pp. 631-632, 16 figs. on supp. plates. Review of methods heretofore employed for determination of sulphur distribution; describes new process making use of mercury chloride and gelatine paper; advantages over Baumann process.

STEEL CASTINGS

NI-CR-FE AND CO-CR-FE. The Production and Uses of Ni-Cr-Fe and Co-Cr-Fe Castings, J. F. Kayser. Foundry Trade Jl., vol. 35, no. 558, Apr. 28, 1927, pp. 351-354, 4 figs. Describes present position of those alloys which are suitable for production of castings and considers in some detail their future; cast magnets; stainless alloys.

STEEL, HEAT TREATMENT OF

DEVELOPMENTS. Heat Treatment in Engineering, R. M. Bird. Engrs. and Eng., vol. 44, no. 4, Apr. 1927, pp. 90-91. Engineers recognize fact that heat treatment in its largest sense has important part in material engineering; this applies to non-ferrous metals as well as to steels.

TEMPER HARDENING. The Phenomenon of Temper-Hardening in Steels, T. Matsushita and K. Nagasawa. Iron & Steel Inst.—advance paper, no. 12, for mtg., May 1927, 16 pp., 12 figs. It was found that magnetic hardness of quenched carbon steels first decreased with rise of tempering temperature, but that from temperature of 400 to 450 deg. cent. it began to increase, and attained maximum at 475 to 550 deg. then decreasing again as tempering temperature increased further; increase of magnetic hardness caused by tempering is here called "temper-hardening"; phenomenon is accompanied by corresponding changes in mechanical properties, such as hardness, tensile strength, impact resistance, etc.

TERMINOLOGY. Report of Committee A-4 on Heat Treatment of Iron and Steel. Am. Soc. for Testing Matls.—advance paper, no. 11, for mtg., June 20-24, 1927, 5 pp., 2 figs. Proposed tentative definitions of terms relating to heat-treatment operations.

STEEL INDUSTRY

FRANCE. Some Aspects of the Technical and Economic Conditions of the Heavy Metallurgical Industry of the East of France, with Particular Reference to the Utilization of Gases and Motive Power, J. Seigle. Iron and Steel Inst.—advance paper, no. 13, May 1927, 72 pp., 16 figs. Iron ores and their uses; coke for blast-furnaces; coal; manufacture of pig iron; production of blast-furnace gas; cleaning and uses of blast-furnace gases; Cowper stoves; heating of various types of furnaces; power generation; electrical energy; electric drive for rolling-mill trains; manufacture of basic steel; open-hearth steel works. See also abstract in Iron & Coal Trades Review, vol. 114, no. 3088, May 6, 1927, pp. 713-719, 12 figs.

STEEL MANUFACTURE

DUPLEX PROCESS. The Manufacture of Steel in India by the Duplex Process, B. Yaneske. Iron & Steel Inst.—advance paper, no. 9, for mtg., May 1927, 29 pp. Duplex process is combination of Bessemer and open-hearth methods of steel manufacture, and consists of desiliconizing, and partly or almost completely decarburizing, molten pig iron from blast furnace in an acid-lined Bessemer converter, and subsequently dephosphorizing metal in basic open-hearth furnace; this process is practiced successfully in India by Tata Iron and Steel Co. under difficult climatic conditions with more than 99 per cent of native labor at their works at Jamshedpur. See also abstract in Iron & Coal Trades Rev., vol. 114, no. 2088, May 6, 1927, pp. 727-732.

News of the Society

AN UNUSUAL EVENT

MORE than 25,000 manufacturing executives and scientists of the metal-working and metal treating industries from every state in the Union, Canada and many foreign countries, will assemble in Detroit to participate in the numerous technical sessions to be held by the society during the week of September 19 and to attend the National Steel and Machine Tool Exposition. It is seldom that four national technical societies interested in the metal industry, convene simultaneously in the same city, yet the five days of the week of September 19 will witness such an unparalleled event at Detroit.

The four societies participating are the Society of Automotive Engineers, the American Welding Society, the Institute of Metals and the American Society for Steel Treating.

More than 300 firms from the metal-working centers of the United States and some foreign countries will use 85,000 square feet to exhibit their products under actual operating conditions at the mammoth Convention Hall and it will be the largest factory equipment exposition ever held in America.

SOCIETY OF AUTOMOTIVE ENGINEERS PROGRAM

THE Production Meeting of the S. A. E. will be held in Detroit on September 21 and 22 during the National Steel and Machine Tool Exposition. Gene Bouton of Chandler Motor Car Company and John Younger of Ohio State University are in charge of the plans which call for several interesting production sessions as well as discussion and inspection of some important production problems that are being preformed in the automotive manufacturing industry at Detroit. These Production Meetings have always attracted a large number of production engineers, and the Convention this year will undoubtedly surpass from the standpoint of attendance and the importance of program any previously held. The S. A. E. meetings will be held at Hotel Statler, headquarters for both S. A. E. and A. S. S. T.

TECHNICAL PROGAM OF AMERICAN WELDING SOCIETY

THE Program Committee of the American Welding Society is already engaged in the preparation of a high grade program for the Detroit Convention. A number of papers have already been received and a number of others are in preparation so that the program is going to be one of high caliber and so constituted as to be extremely interesting and worth while to the members of the American Welding Society and their guests assembled at Detroit during the week of September 19. The techinacl sessions will be held at the American Welding Society headquarters hotel, the Book-Cadillac.

The welding and cutting exposition held under the auspices of the American Welding Society and in co-operation with the National Steel and Machine Tool Exposition in Detroit the week of September 19 will be the largest exhibit

of its kind ever held. A special section of Convention Hall of over 10,000 square feet has been set aside for the welding exhibit. Consequently all of the exhibits will be grouped together and the opportunity to observe the latest and best equipment and developments in this line. The two previous exhibitions of the A. W. S. at Boston and at Buffalo occupied only about half the space that will be devoted to welding at the Detroit show.

INSTITUTE OF METALS

THE Institute of Metals Division of the American Institute of Mining and Metallurgical Engineers have arranged to hold their annual fall meeting at Detroit the week of September 19 during the National Steel and Machine Tool Exposition. This is the first year in which the Institute has had simultaneous meetings with the A. S. S. T. This is, however, a very happy combination inasmuch as what the A. S. S. T. is to the ferrous, the Institute of Metals is to the nonferrous industry. A splendid spirit of co-operation is being evidenced through W. M. Corse, secretary of the Institute of Metals Division, and arrangements are being made for one joint session of the A. S. S. T. and the Institute of Metals at the Statler for Wednesday afternoon, at which time papers will be presented pertaining to subjects of common interest to members of the two organizations.

The annual Institute dinner will probably be held on Wednesday evening, and the Institute will participate with the American Society for Steel Treating, American Welding Society and Society of Automotive Engineers in various other features of entertainment.

Technical meetings and Hotel Headquarters at Book-Cadillac Hotel.

PLANT INSPECTION

EXTENSIVE preparations are being made for inspection of Detroit manufacturing plants during the Convention and National Steel and Machine Tool Exposition the week of September 19. Every year more and more interest has been manifested in the plant inspection trips and members and guests attending the Conventinon realize that they offer an exceptional opportunity to get new ideas. Detroit offers splendid plant inspection opportunities because of the large manufacturing diversity in iron and steel products and also since production is developed to the Nth degree.

REDUCED RAILROAD RATES

REDUCED railroad fares have again been awarded to the members of the American Society for Steel Treating for the Detroit Convention. This means that you and your immediate family, wife and children will be privileged to purchase tickets for your trip to Detroit at fare and one-half for the complete journey. Tickets will be on sale beginning September 15 and good for return up to September 29. From distant points such as California the date sale and return limit are extended beyond the dates mentioned. These certificates may be issued only to members of the A. S. S. T. All members will receive the certificates sufficiently in advance.

News of the Chapters

STANDING OF THE CHAPTERS

DURING the month of May there were 186 new and reinstated members, while 48 were lost through arrears and 26 resignations, leaving a net gain for the month of 112 as compared with a gain of 84 for May of last year.

In the following tabulation there appears the relative membership standing of the 32 chapters and 3 groups of the Society as of June 1, 1927.

GROUP I		GROUP II		GROUP III	
1. Detroit	458	1. Hartford	136	1. Los Angeles	79
2. Chicago	408	2. Milwaukee	129	1. Tri City	79
3. Philadelphia	364	3. Lehigh Valley	128	3. New Haven	75
4. Pittsburgh	346	4. Golden Gate	108	4. Washington	70
5. Cleveland	331	5. Dayton	100	5. Southern Tier	67
6. New York	281	6. Cincinnati	96	6. Rockford	66
7. Boston	254	7. Indianapolis	95	7. Toronto	60
		8. Montreal	91	7. Worcester	60
		9. Syracuse	91	9. Rochester	59
		10. Canton-Massillon	90	10. Providence	54
		11. St. Louis	84	11. Columbus	48
		12. Buffalo	60	12. Schenectady	45
		13. North-West	54	12. Fort Wayne	45
				14. Springfield	32
				15. Notre Dame	19

GROUP I—Detroit still heads this group with a lead of 50 over its nearest competitor, Chicago. Last month Detroit's net gain was 29, one of the largest any chapter has had for some time. Just last week, E. O. Mann, assistant chief metallurgist at Chevrolet, sent in 39 applications, all from the Chevrolet plant. These 39 applications started with the general manager and continued with the rest of the executives. Mr. Mann now holds the record of having secured the largest number of applications sent in at any one time, as well as the largest number secured at one time from a single plant. Congratulations to Mr. Mann and the Detroit chapter! Chicago, Philadelphia and Pittsburgh show a gain while Cleveland shows a loss; New York holds its own and Boston a slight loss.

GROUP II—While Hartford suffered a loss of 2, it was not sufficient to dislodge this chapter from position 1. Milwaukee also had a loss, while Lehigh Valley showed a gain. Golden Gate had a loss of 8 members, but still retains position 4. Dayton, with a net gain of 6, advanced from 8th to 5th position. Cincinnati by a gain of 1, was able to pass Indianapolis and go from 7th to 6th place. Montreal and Syracuse are still 8 and 9, while the Canton-Massillon chapter which joins the A. S. S. T. family with an

initial membership of 121, has 90 paid-up memberships and holds 10th place. St. Louis, Buffalo and North West were moved down one place, due to Canton-Massillon.

GROUP III—Los Angeles and Tri City are in a tie for position 1, Tri City with a net gain of 3 having replaced New Haven in position 2. Southern Tier with a gain of 4 passed Rockford and goes into 5th place. Toronto and Worcester are still tied for 7th place with 60 members each. Last month Rochester, Toronto and Worcester were all tied but a loss of one member by Rochester brought it down from 7th to 9th place. Columbus with a net gain of 16, advances from 14th to 11th place. Fort Wayne with an addition of 1, goes into a tie with Schenectady for No. 12. You will observe a new name in this group—that of Notre Dame. This is a student group organized by Prof. Mahin of the University of Notre Dame and is composed largely of juniors and seniors in the metallurgical courses at this school.

The following table shows the net gain for the first 9 months of 1926 and 1927 as compared with the same 9 months of 1925 and 1926.

NET GAIN

	1925		1926
September	69		107
October	64		110
November	58		85
December	53		41
January (1926)	8	(1927)	41
February	77		41
March	93		88
April	121		85
May	83		112
	626		710

So far this year there has been a net gain of 710 members, an increase of 84 over the 9 months last year, or at the rate of 18 per cent for the year.

The total membership of the Society to date is 4721.

BUFFALO CHAPTER

The May meeting of the Buffalo Chapter of the American Society for Steel Treating was held at the Hotel Statler, May 12, 1927.

The meeting was called to order by Chairman Armstrong, at 8:30 p. m. and the minutes of meeting March 31, 1927, read and approved.

Mr. Lansdown, who is connected with the district attorney's office, was introduced to explain the Baumes Law. Following Mr. Lansdown's interesting discussion F. R. Palmer of Carpenter Steel Co. was introduced as the technical speaker of the evening. The principal part of the talk was on tool steel parts and pictures were used to illustrate the most interesting paper which Mr. Palmer presented. A lengthy and interesting discussion followed.

About forty members and guests attended.

Lunch was served after adjournment. *B. Clements.*

CHICAGO CHAPTER

The Chicago Chapter of the American Society for Steel Treating held their sixth annual outing at the Hartman House, Wheeling, Illinois, on Saturday, June 11, 1927. A chicken dinner was served at 2:00 p. m. during this time music and other entertainment was furnished, after dinner the members of the chapter and their friends took part in base ball, horse shoe pitching, a tug of war and various other out door sports.

A. M. Steever.

CLEVELAND CHAPTER

On Friday evening, April 22, 1927, J. A. Succop of the Heppenstall Knife and Forge Company, Pittsburgh, addressed the chapter on "The Making and Treating of Die Blocks." His subject was mainly featured by films, which aided him in the telling the complete story of a die block from the selection of the raw material to the shipping of the finished block.

The speaker stressed the point, when he told with what care the blocks are heat treated to secure uniformity, explaining that due to this care it is advisable to purchase, whenever possible, a heat treated block and not attempt to do it yourself. There were plenty of questions to make a very interesting meeting and many brought forth their troublesome problems.

About 140 members and guests were present about 40 being present for dinner at Carnegie Hall restaurant.

On Friday evening, May 20, 1927, the chapter was addressed by Dr. William Blum, Chemist of the Bureau of Standards, Washington, D. C., on the subject of "Applications of Chromium Plating." There has been wide interest in the subject of chromium plating and the speaker aroused considerable interest by his unprejudiced and able talk.

Dr. Blum discussed the characteristic properties of chromium plating and the numerous uses to which it has been applied. His opinion of certain suggested applications brought out many interesting facts which enlightened many who are experimenting with chromium plating.

The speaker passed around many plated articles as printing plates, gages, steel plates, etc., and in fact gave an entertaining as well as instructive talk.

There were about 160 members and guests present of whom 30 attended dinner at Carnegie Hall restaurant.

A. E. Buelow.

COLUMBUS CHAPTER

The second meeting of the Columbus Chapter of the American Society for Steel Treating was held Tuesday evening May 24, 1927, at the Fort Hayes Hotel.

A dinner again preceded the regular meeting and was attended by 34. The regular meeting was called to order at 8 o'clock by the chairman

Mr. G. S. McFarland. There was a very good attendance of both members and guests for this meeting. The Chapter decided to hold the meetings regularly the third Tuesday of each month.

F. R. Palmer, metallurgist for the Carpenter Steel Company, of Reading, Pa., was the speaker of the evening. His talk was accompanied by some very interesting slides and covered the field of tool design, selection of proper steels, machining, heat treatment, grinding, and the improper use of tools. In each instance he pointed out how tool failures may be caused. A very interesting discussion followed, in which a goodly number participated. Mr. Palmer's paper was very well received by all those present, everyone feeling that they had gained something from this interesting paper.

G. D. Moessner.

FORT WAYNE GROUP

The annual meeting of the Fort Wayne Group of the American Society for Steel Treating was held on May 24, 1927, following a dinner at the local Y. M. C. A. During and following the dinner, the membership was entertained by local musical and "magical" talent.

The business meeting, which followed, consisted of the approving of minutes and the annual report of the secretary-treasurer, and the election of officers for the coming year. Those elected were:

Chairman—W. E. McGahey, Northern Ind. Gas & Elec. Co., Ft. Wayne.

Vice-Chairman—H. B. Knowlton, International Harvester Co.

Secretary-Treasurer—Jno. A. Hansen, S. F. Bowser & Co., Ft. Wayne.

Executive Committee—Geo. E. Tibbits, Fred C. Smith, Jos. Doepker, H. J. Kiess, Perry Cooper.

The speaker of the evening was Jordan Korp of the Leeds and Northrup Company. He gave a lecture on "The Heat Treatment of Tool Steels" and was most enthusiastically received. Many members stated that never before had they heard the subject discussed so clearly and in such a systematic manner. All were very much pleased.

Fred C. Smith.

GOLDEN GATE CHAPTER

The Golden Gate Chapter of the American Society for Steel Treating held its regular May meeting Wednesday the 11th at the Engineer's Club, San Francisco. After the usual dinner the meeting was called to order in the lounge of the club by H. E. Gray of the Bethlehem Shipbuilding Corp. Mr. Gray first called for the report of the nominating committee and the chairman of the committee H. S. Taylor presented the names of the following gentlemen to serve the section for the ensuing year.

Dr. Welton J. Crook, Chairman, Stanford University, S. C. Alexander, Vice-Chairman, California-Hawaiian Sugar Refining Corp., San Francisco, S. R. Thurston, Secretary-Treasurer, Bethlehem Shipbuilding Corp., San Francisco, F. B. Drake, H. E. Gray, J. H. Gumz, A. C. Naish, R. T. Wise, F. L. Wight, Cecil Hawley, D. H. Grubb, Geo. Batten, J. S. Fowler and H. S. Taylor were the names offered as members to serve on the executive committee.

The Chapter voiced its approval of the slate offered and by acclamation declared the entire ticket elected. Mr. Gray then called upon the newly elected chairman for a few remarks. Dr. Crook in response suggested that he would be highly honored and glad to serve provided his intended trip to England and the continent of two months duration would not interfere. He commended the course in elementary metallurgy made possible thru the efforts of the chapter and the Oakland High School and under the immediate direction of Mr. Taylor and Mr. Moody. "However," said Dr. Crook "it has been my experience as a mining engineer, metallurgist and instructor in this branch of applied science that much more progress is made if in connection with the lecture room a laboratory course of instruction can be supplemented." Dr. Crook then urged each member of the section to give some careful thought to the best means of establishing and maintaining a laboratory.

Mr. Alexander in a few words indicated that he would endeavor to assist Dr. Crook in every way to make the ensuing year a success.

The chairman then announced the first speaker of the evening R. J. Neill of the Haynes Stellite Co. Mr. Neill gave a very entertaining dissertation on the manufacture, properties and uses of the "super alloy" stellite. He pointed out the advantages of this chromium, cobalt, tungsten alloy for small tools, cutlery, milling cutters, oil mill bits, etc. In fact this solid solution or eutectic, alloy as the case may be is well suited for almost any tool or part requiring resistance to heat, abrasion or corrosion. The elucidation of the microstructure of stellite was, from a standpoint of metallography, worthy of comment. Also the method of welding the stellite bit to a ferrous shank and the manner of spreading it on, was productive of a number of questions.

Near the close of Mr. Neill's talk when it was brought out that from a dollars and cents and production basis stellite was superior to steel from 2 to 1 to 4 to 1, three high speed steel salemen fainted, one of whom had to be carried out.

Mr. Neill was followed on the program by W. L. Harvey of the Caterpillar Tractor Co. Mr. Harvey's discussion of "Meehanite" was quite enlightening in that it showed that a ferrous alloy similar to cast iron (2-4 to 2-7) was also highly resistant to corrosion, thermal vibrations and abrasion. The report on this alloy was supplemented by government tests which showed a Brinell hardness of 261 to 268 and a tensile strength of 65,000 pounds per square inch. The elongation was also in some cases quite comparable to ordinary cast iron being as high as 0.57 per cent for a 2-inch gage length. In some other instances however the elongation was somewhat disappointing being as low as 0.003 of 1 per cent. After listening to the first two papers of the evening, it seemed as if the metallurgists at last had corrosion subdued.

B. W. Wells of the Carborundum Company gave an interesting and instructive talk on abrasives, their production and uses. His talk was chiefly of carborundum and he pointed out many of the present day conveniences would not be possible had it not been for the classical experiment and continued research of Dr. Acheson started back in 1891. After the talk about

20 minutes of moving pictures were shown which to many of us was indeed a rare treat. After Mr. Wells a few remarks by Krit Icklepoint, that worthy investigator, were well received by the chapter. A vote of thanks and appreciation was given the speakers for their part in making a very enjoyable evening.

There being no further business the meeting adjourned sine die.

S. R. Thurston.

The regular June meeting was held at the Athens Athletic Club, Oakland, Wednesday, June 8, 1927.

The usual dinner which preceded the meeting was attended by 68 members and guests. This number was augmented by 12 or 15 at the meeting.

F. B. Drake, former chairman of the section, called the meeting to order. The minutes of the preceding and executive meetings were read and approved.

Messrs. Grubb, Taylor and Alexander, chairmen of the membership and educational and program committees respectively, spoke very briefly, outlining their plans for the coming year.

Mr. Drake voiced his appreciation for the support accorded him during his tenure of office and urged everyone to put forth his best effort to the end that Golden Gate Chapter shall grow and prosper. Just prior to introducing William Cohn of Pittsburg as chairman of the evening, Mr. Drake was given a rising vote of thanks and a rousing cheer for his energy and fidelity while chairman.

William Cohn, assistant general superintendent of the Columbia Steel Corporation, then assumed command and in his opening remarks read the lines by H. D. Hubbard "I am Steel." This was followed by a brief resume of the progress of the Corporation from 1910 when 400 tons of steel per month were produced in the plant employing 125 men, to 1926 when the tonnage had been increased to 31,200 per month with 3,000 men earning a one half million dollar monthly payroll. Mr. Cohn pointed out that approximately 85% of the pig used on the coast came from Columbia properties in Utah, where are operated coal and iron mines and coke ovens. He also said that geologic estimates and surveys indicated sufficient raw material to last 100 years.

Referring to the Torrence and Pittsburg plants, he said that only 38% of the scrap came from the state, the balance coming from Central America, Mexico, Hawii, etc., also fluorspar, and the ferroalloys were brought to California.

Otto Kresse, superintendent of the open-hearth, was introduced and traced the early history of open-hearth steel from 1861 up to the present. We were told that 87 per cent was now basic steel. Mr. Kresse then took us underneath the platform, and by the aid of multi-colored drawings, pointed out the operation of the checker and flue system, after which he burned in a 10 day bottom in approximately 10 minutes (rapid work, Otto). Having the furnace in readiness Mr. Kresse then put in the charge of limestone, scrap, pig, coke and in due time was able to pour a test ingot and estimate the carbon to within 0.04 per cent. When the heat was ready to tap, certain ad-

ditions were made to the ladle and a bottom pour made—Shortly after the ingots were stripped, placed on cars and were sent on their way to the rolling mill.

Before taking the first 12 ingots to the mill for reduction into sheet and bar stock, Mr. Cohn called upon A. M. Harris for a vocal selection. An encore followed and we all wondered why Mr. Harris did not forego Pittsburg for R. S. V. P. or some local station where we might hear him by the turn of the dial at any time.

Mr. Cohn first chucked 95 ingots into soaking pits 6x102 inches and by the aid of water cooled skids as mechanism and oil as fuel, in five hours' time heated the ingots to a working temperature of 2300 degrees Fahr., when they were taken to a 26-inch, 3-high blooming mill, operated by a 1200-H. P. motor and given a 6 to 1 reduction. Hence they were taken to the 18-inch mill and in five passes, reduced to size weighing 13½ pounds per foot, with a plus or minus tolerance of not over 2½ per cent. This reduction operation was made more clear also by the aid of sketches.

Bert Lanz, superintendent of the sheet mill, after breaking a few rolls for an alibi, proceeded to roll out, in five mills, sheets 30x120 inches, and 16 to 30 gage with amazing rapidity. After he had gotten out a few sheets as samples and to show just what he could do, Mr. Lanz proceeded in some elaboration to explain in more or less detail the art of working the hot mill, heat in pairs, function of the roughing mill, box anneal, pickling and galvanizing. Finally Mr. Lanz stated that 660 different sizes of sheets were produced, but nary a pillow case in Pittsburg.

After Mr. Lanz had concluded his interesting talk Mr. A. Showalter recited in a very creditable manner, "Spartacus' Address to the Gladiators."

Mr. Cohn next, in eleven passes by the aid of correct annealing temperatures, proceeded to produce rods and wire, getting in some instances as high as 50 per cent reduction—starting with a rod 7½ feet long and finishing with a wire 1750 feet in length was in itself some pull.

Mr. E. Barber, superintendent of the wire and nail mill, next took the floor and mentioned wet and dry cold drawing processes, going into detail for the dry method as used at Pittsburg.

Explaining the methods of removing mill scale, lubricating with hydrated ferric hydroxide, lime, grease and soap and drawing a rod of an original area of 0.20 to 0.054 inch and approximately a 93% reduction, was considered some draft. Hard drawn wire being used for nails and high carbon for spring wire.

Spring wire is annealed after three drafts in an air furnace and then placed in a lead bath. When finished it has a tensile strength of 200,000 to 240,000 pounds per square inch. It is then annealed at 1600 to 1625 for a long soak.

Mr. Barber speaking of nails said that the disposition of the 2,000 kegs daily output caused the shipping department more concern than the nail department. The speaker held up what was reputed to be one of the biggest nails made and one of the smallest. We saw the larger and took his word about the smaller.

A general discussion conducted by Mr. Cohn followed.

It was agreed by all, including Mr. Garlinger, that it was a humdinger of a meeting and we all will look forward to another Pittsburg evening.

Thanks to Messrs. Cohn, Kresse, Lanz, Barber, Harris, Showalter.

S. R. Thurston.

INDIANAPOLIS CHAPTER

On Monday evening April 25, the local chapter held their regular monthly meeting at the Auditorium of the Y. M. C. A. Dinner was served to approximately 75 members and guests many of whom were from near by cities and towns. Immediately after the dinner a Minstrel show was staged by several of the boys from the Link Belt Company and many scintillating jokes showed that the members were real "heat treaters."

Harry B. Northrup, metallurgist for The J. W. Kelley Company, of Cleveland, Ohio, was scheduled to deliver the address on Carburizing and Quenching but because of unavoidable conditions he was compelled to cancel the trip and Mr. Jerry Burns read the address. Being a very interesting and important subject, a heated argument followed the address showing that all present were trying to obtain better results in the use of these two necessary operations in making highly stressed parts of steel. Many shop kinks were fully explained.

C. H. Beach.

On Monday evening, May 23, the local chapter presented the final regular monthly meeting for the Season 1926-1927 and all members began turning their attentions toward the Ninth Annual Convention to be held at Detroit and to the program for the coming year. More than fifty members and guests were present for the dinner which immediately preceded the addresses of the evening.

F. R. Palmer favored us with a return engagement. Mr. Palmer being the metallurgist for The Carpenter Steel Co., Reading, Pa., and a careful investigator of the make-up and actions of tool steels presented an illustrated informal talk on "Something New in the Heat Treatment of High Speed Steels," and the close attention paid by the listeners showed that all were deeply interested in the subject particularly as they themselves were working every day trying to make better tools, etc. Prolonged discussion brought forth numerous "Shop Kinks" used by many in handling their own problems.

As the meeting was arranged primarily for the benefit of our out-of-town members and guests, the boys from The Delco Remy Division of The General Motors Corporation of Anderson, Indiana, planned a very enjoyable entertainment which included the well known Mr. Max Terhune, Ventriloquist and Imitator, who promoted spirited laughter by his Barn Yard imitations. Messrs. Curtis Crim and Counceler gave their interpretations of the latest dances and showed that they were past masters of the harmonica.

The nominating committee submitted their report on recommendations for officers for the coming year and gave a single ticket, all of whom were unanimously elected. These included:

Chairman: Mr. Clarence H. Beach, District Sales Representative for Bliss & Laughlin, Inc., who has acted as Secretary-Treasurer for the local chapter during the past two years.

Vice Chairman: A. T. Haggerty, Metallurgist for the Muncie Products Division of The General Motors Corporation of Muncie, Indiana.

Secretary: James S. Marlowe, of The J. S. Marlowe Co., Indianapolis.

Treasurer: Edward J. P. Fisher, Metallurgist for The Diamond Chain & Mfg. Company, Indianapolis.

Deep regrets were expressed because our members and guests were fully expecting a visit by the National Officers, Messrs. J. Fletcher Harper and William H. Eisenman, but were disappointed because of their failure to appear on account of business reasons.

Clarence H. Beach.

LOS ANGELES CHAPTER

The May meeting of the Los Angeles Chapter was held at the Los Angeles City Club, Wednesday evening, May 11, 1927. The announcements of the meeting, mailed to the members served their purpose well, and brought out an unusually large attendance.

After an excellent dinner at the Club, the meeting was called to order at 7:45 by Chairman Stiles.

The recent resignation of Secretary-Treasurer, E. C. Black was read and accepted, with a vote of thanks for his excellent work during the past two years. Mr. Black leaves Los Angeles to become associated with the West Michigan Steel Foundry Company at Muskegon, Michigan. Mr. Black leaves in the Los Angeles District a host of friends who, sorry to see him go, nevertheless, all wish him every success in his new position.

The distribution of prizes for work in the membership contest was next in order. The first prize, "Bullen's Steel and Its Heat Treatment," was awarded to Mr. E. C. Black. The second and third prizes, A. S. S. T. pencils, were awarded to H. J. Barton of the E. A. Jorgensen Steel Company and W. D. Cleghorn of the Jas. H. Knapp Furnace Company.

Following the distribution of the prizes the annual election of officers was held. Mr. Wade Hampton of the Hughes Tool Company was elected Chairman. The Vice-Chairman is Mr. C. H. Fromme of the Axelson Machine Company, and the Secretary-Treasurer is H. V. Ruth of Ducommum Corporation, all of Los Angeles.

A vote of appreciation was given by the Chapter for the splendid work of the retiring officers and assurances of assistance to the new officers in carrying out the objects of the Society, were made by the retiring officers.

Following the business meeting the first two papers of the series arranged for the next six months were given. The first paper "Heat Treating Responsibilities" given by Morris B. Pendleton of the Plomb Tool Company was an excellent one. The paper brought out in a very vivid manner the varied responsibilities of the heat treater, the employer and the relation of both to the ultimate consumer.

After the paper by Mr. Pendleton, Fred Arnold, of the Plomb Tool Com-

pany gave an illustrated talk on "Heat Treating Terms." The paper had as its principal idea the purpose of giving a thorough understanding of the definitions and heat treating terms to the newer members, so that in the succeeding series of talks all members would find the technical terms more helpful in obtaining the most good from the talks and "Transaction Reviews."

Mr. Arnold will continue his interesting and excellent talk at an early date, to fit in with the other talks as the series progresses.

Several new applications for membership were received which should help Los Angeles Chapter maintain its place at the top of Group III. *H. V. Ruth.*

The June meeting of the Los Angeles Chapter was one of the most interesting meetings since its organization. Much of the credit for such an interesting meeting is due to the personal efforts of our newly elected chairman, Wade Hampton.

This meeting was held Thursday evening, June 9, in the banquet room of The Los Angeles Creamery Company. More than fifty members and guests were present at the dinner, and a number more arrived to hear the papers and the open discussions.

Immediately after the excellent dinner, W. D. Cleghorn, of the James H. Knapp Company, was presented with an A. S. S. T. pencil in token of the Chapter's appreciation of his enthusiastic services in the membership drive. Mr. Cleghorn was second prize winner.

Following the business meeting W. H. Laury, Research Engineer of Axelson Machine Company, gave a very interesting paper on "Thermal Critical Points of Steel." He said in part: "Structural and other changes in steel take place at temperatures known as the thermal critical points, or critical ranges, because they are points in the cooling or heating of the metal that are marked by the spontaneous evolution or absorption of heat. The most marked of these is the range commonly called the point of recalescence and point of decalescence.

"All critical ranges are denoted by the letter 'A,' followed by either the small letter 'r,' an abbreviation of the French word 'refroidissement,' cooling, or the small letter 'c,' which stands for 'chauffage,' signifying heating. These signs, Ar and Ac are further modified by the numerals 1, 2, 3, indicating the point of recalescence, the second and the third points encountered on heating, respectively. Thus, Ac_1 means the first critical point passed upon heating the steel, and so on.

"It can be readily understood that the condition surrounding the physical characteristics of steel have a very close bearing upon the accurate heat treatments as applied to particular steels. Just as the micrometer serves as a means to measure close precision, so the pyrometer registers the closeness with respect to required heat treating temperatures. Just as specified sizes with tolerances on dimensions are required in manufacturing a particular shaped piece, so the critical points, or transformation ranges, must be known to the treater. It, therefore, resolves itself to a condition where certain ranges of temperature must be used in conjunction with the specific critical point for accuracy in a heat-treating operation."

The other speaker of the evening was J. H. Spade, of Ludlum Steel Company, who spoke upon "Classification of Steels, with Some Pertinent Points of Processing Finished Articles."

Mr. Spade took up briefly the modern processes of making steel, open hearth, basic and acid, Bessemer, tonnage and crucible type electric furnace and crucible, pointing out the principle distinctions between the various methods, such as character of furnace linings and slags used with each.

A brief discussion of the differences of alloys in the various stainless steels and stainless irons as well as the more proper application of each, came in for a part of the talk.

An interesting conclusion to the speaker's paper was furnished by the exhibiting of failures caused by grinding ball bearing steel, in the hardeneed condition, with improper grinding wheels, and a general warning was sounded regarding the proper selection of wheels before attempting a grinding operation on any part made of "deep hardening" steel, in the hardened condition. The hot acid etch was used to define the "checked" surface in conspicuous manner.

In the discussions which followed the readings of these papers, both Bill and Jim replied to a great many questions in a manner which showed their wide knowledge of their subjects. The discussions were very interesting.

Our chairman stated that if the chapter were willing, we would in the near future, go to Ventura, Calif., on a visitation trip. The members seemed very anxious to make this trip and Wade appointed a committee to arrange all the details of the trip. The trip to Ventura will be reported at an early date.

H. V. Ruth.

NOTRE DAME GROUP

The first meeting of the recently chartered Notre Dame group of the A. S. S. T. was held for the purpose of organization and election of officers. The officers for the coming year are as follows:

R. C. Spencer, Chairman, Department of Chemistry, Notre Dame, Indiana
F. J. Mootz, Secretary, 1958 Ashland Avenue, Indianapolis, Indiana
E. J. Wilhelm, Treasurer, 1527 So. Michigan St., South Bend, Indiana

The above addresses will remain as such until September.

Much spirit and interest was shown at the first meeting and indications are that the Notre Dame group will be a very active chapter.

Frank J. Mootz.

PHILADELPHIA CHAPTER

The final meeting of the Year 1926-1927 of the Philadelphia chapter was held at the plant of the Henry Disston & Sons Inc., Tacony, Philadelphia. This pioneer saw manufacturing company acted as host to the chapter and its friends and arranged a very splendid tour through its plant which started at 2:00 p. m. and at 7:00 p. m. provided an excellent dinner which was enjoyed by 190 members and friends of the chapter. Just prior to the dinner a very interesting base-ball game took place and among the players

were such individuals as R. M. Bird, A. L. Collins, H. B. Allen and C. Mitchell.

During the course of the plant visitation, opportunity was given for the observing of the manufacture of both crucible and electric steel and the subsequent preparation of the ingots produced into saws, files, trowels etc. The members of the chapter seemed particularly interested in some of the heat treating operations which were shown to them, such as the hardening and tempering of saws etc.

The dinner which was served in the company's cafeteria left no aching voids and was thoroughly enjoyed by all. At the conclusion George Satterthwaite, vice-president of Henry Disston & Sons Co., Inc., made the following short address.

"A year ago when Mr. Coleman and Dr. Patch came to see me to suggest that the annual meeting of the Chapter be held at our plant, they approached the subject as if our company would be bestowing a great favor upon the chapter; they seemed to think that it would be a great privilege to have the meeting here. I thought then and I think now that the shoe was on the other foot. We feel that it is really a great privilege and honor to entertain such a splendid group of earnest people, interested in one great subject,—the treatment of steel.

"You have spent a few hours (I hope pleasant and interesting hours) inspecting some of the departments of our plant, and I hope you have all had an enjoyable afternoon.

"This chapter has grown so large and such a large number of the membership turn out at the meetings that it has become rather a problem to find industrial plants in which Steel Treaters would be interested, with facilities to properly entertain such a large number. We realize that it is hard to show a large group of people through our factory, as many of our operations are small and performed by individuals doing fine hand-work, whereas, in visiting the large steel works, operations are on a larger scale, are more spectacular, and there is usually more standing space available for visitors.

"We realize, also, that our cafeteria here, as suitable as it is for the purpose for which it was built and is being used, is not the most comfortable place in the world to spend an evening, but such as our facilities are, we have offered them this afternoon and do offer them again this evening with the hope that this annual meeting will be pleasant, interesting, and possibly instructive.

"Our business is absolutely dependent upon our ability to properly heat treat steel and so quite naturally, and possibly from a selfish standpoint, we are interested in the Society, in the Philadelphia Chapter, and in the good practical work that is being accomplished, and we firmly believe that what small financial support we have given to this society is money well-spent, for which we have gotten and will continue to get in even greater measure, a very satisfactory return.

"You are probably tired and certainly hungry, and so, in behalf of our company I welcome you to Tacony and to the largest saw manufacturing plant in the world."

After a few remarks by the toast master, H. B. Allen, he intro-

duced Horace Disston who gave a very interesting and at times humorous talk on the history of the Disston Co., and the evolution of the saw. When this talk had ended there was a brief business meeting of the Chapter during which the following new officers were inducted into office. Chairman, James R. Adams, Superintendent Special Production Department, The Midvale Co.; Vice-Chairman, Dr. R. H. Patch, Assistant to the President, E. F. Houghten Co.; Secretary-Treasurer, A. W. F. Green, Sales Metallurgist, The John Illingworth Steel Co., and the following Directors; Messrs. A. L. Collins, Sales Metallurgist, Horace T. Potts and Co.; W. B. Coleman, W. B. Coleman Co.; E. H. Barker, Production and Maintenance Engineer, A. H. Wirz Co., Inc; H. B. Allen, Metallurgist, Henry Disston & Sons, Inc. and R. C. Gebert, Metallurgist, Nice Ball-Bearing Co.

The Year Book for 1927 is being edited by Charles Willits, district sales manager, Central Alloy Steel Corporation and it will be a pleasure to mail copies to anyone sending in their request to the secretary of the chapter.

Arthur W. F. Green.

PITTSBURGH CHAPTER

The Pittsburgh Chapter held its June meeting at the Alcoma Country Club on the 9th.

A number of the members enjoyed playing golf during the afternoon.

At 6:30 a dinner was served in the club house after which T. D. Lynch told of his expected trip to Europe in August.

At the usual time, Chairman James P. Gill called the meeting to order and, after dispensing with the business of the evening, welcomed George M. Eaton of The Molybdenum Corporation, who led the evening's discussion on helical spring manufacture and reasons for failure. Many theories and reasons were given during the discussion by various members and at adjournment many expressed their appreciation of the information obtained at this meeting.

Harry A. Neeb, Jr.

RHODE ISLAND CHAPTER

The May meeting of the Rhode Island Chapter rounded out a very well balanced year. The afternoon was taken up by a visitation to the Universal Winding Co., where we were shown the manufacture of winding machines from the pig iron to the finished and tested product.

The "Universal-ity" of these machines can well be judged by the fact that they are in use in 26 countries outside of the United States. The winding machine is the result of 35 years of improvement and due to the high production demand are now progressing into the use of alloy steels.

We witnessed the tapping of one of their cupolas and the pouring of the moulds. Mr. Clarkin, foreman of heat treatment, demonstrated the carburizing and hardening processes very thoroughly.

We were conducted through the inspection department where the requirements are very rigid, due to the changeability of parts for different climates and countries. The experimental and engineering departments were of exceptional size.

A very elaborate lunch was served "on the Pawtuxet", after which a

real get-together and discussion was led by Mr. Parks. A rising vote of thanks was extended to the Universal Winding Co.

The members and guests journeyed down to the Providence Engineering Society rooms where the annual meeting was held. Vice Chairman Eugene Sullivan presided owing to the illness of Mr. Wray. The secretary was authorized to cast one ballot for the officers chosen by the nominating committee to serve the chapter for the coming year.

Frederick H. Bishop, vice president of the Universal Winding Co., gave an illustrated talk on the practical application of the winding machines as applied to all classes of yarns and fiber and even wire.

E. G. Peterson.

ROCHESTER CHAPTER

On the second Monday of each month from Sept. to April inclusive the Rochester Chapter held regular monthly meetings. There were also held three special meetings during this period. The average attendance per meeting was 36 or 60% of the total membership.

Each meeting was preceded by a dinner at the Mechanics Institute with an average attendance of twenty-five, both members and visitors.

Following is a list of the meetings held with the Speakers and Subjects:

Date	*Speaker*	*Business Connection*	*Subjects*
Sept. 27/26	B. H. DeLong Chief Metallurgist	Carpenter Steel Co.	The Hardening of H. S. Steels by a Novel Method.
Oct. 11/26	J. P. Gill Chief Metallurgist	Vanadium Alloys Co.	H. S. Steel
Oct. 14/26	Dr. Wm. M. Guertler Director Metall Institut der Technischen Hochschule.	Berlin, Ger.	The recent developments in Light Alloys in Germany and the possibilities of new developments in the future.
Nov. 8/26	Dr. P. D. Merica Director of Research	International Nickel Co.	Nickel in Cast Iron
Nov. 22/26	F. D. Bowman Advertising Mgr.	Carborundum Co.	"Jewels of Industry" (Refractories and Abrasives)
Dec. 13/26	R. H. d'Arcambal Sales Mgr. & Metallurgist	Pratt & Whitney Co.	Carbon Steels & H. S. Steels used in manufacture of Small Tools & Metallurgical Control

Jan.	10/27	Dr. E. C. Bain Res. Met. Eng.	Union Carbide & Carbon Corp.	Application of the X-Ray to Metallography
Feb.	14/27	S. P. Rockwell	S. P. Rockwell Co.	Hardening by the Dilatometric Method.
Mar.	16/27	F. W. Lounsberry Vice-Pres.	Atlas Crucible Steel Co.	Tool Steel Failures. Their Cause & Cures
Mar.	28/27	C. H. Bierbau, Con. Met. & H. R. Corse Gen. Sales Mgr.	Lumen Bearing Co.	Heat Treatment of Bronzes
Apr.	11/27	Dr. S. L. Hoyt Res. Met.	Gen. Electric Co.	Elements of Metallurgy
May	9/27	Election of officers	for 1927-1928	
		Chairman	G. C. Van Vechten	
		Vice Chairman	C. F. Wattel	
		Secy.-Treas.	I. C. Matthews.	
		Balance Executive Com.	F. W. Arvine	
			D. M. Strauchen	
			J. E. Ryan	
			H. J. LeClaire	
			E. S. Roscoe	
			C. E. Codd	

It should be noted that the above list includes subjects covering both ferrous and non-ferrous metallurgy, talks on apparatus and equipment and general information which was both interesting and instructive to all those in attendance.

At all of the meetings either slides or motion pictures were shown. Also several of the speakers had samples representative of the topics covered.

Keen interest was maintained by all of the members and guests, who universally discussed each subject at length, and many important phases pertaining to these subjects were covered.

The Rochester Chapter wish at this time to publicly thank each and every speaker and without question would highly recommend them and the subjects as given to any of the other Chapters of our society, since the above program has been one of the most fruitful and educational seasons that our chapter has enjoyed.

C. F. Wattel.

SCHENECTADY CHAPTER

The annual meeting of the Schenectady Chapter was held on May 26 at Riverwood Inn, Amsterdam Road. A turkey dinner with all the fixings was served at 7 p. m. Previous to this light sports were indulged in. The winners of the prizes being Mr. R. M. Cherry and Mr. C. B. Buxton.

The election of officers followed the turkey dinner and the following were elected for the coming year.

Samuel L. Hoyt, Chairman, Research Laboratory, General Electric Co., Schenectady, N. Y.

Prof. M. F. Sayre, Vice-Chairman, Union College, Schenectady, N. Y.

J. G. Hicks, Secretary-Treasurer, American Locomotive Co., Schenectady, N. Y.

Then came the "big event" of the evening in the form of a MOCK TRIAL. Following is the line up:

JUDGE .....Chas. M. Hughes, Lawyer
DEFENDANT.....George Ramsey
DISTRICT ATTORNEY.....George H. Wright
HIS LEGAL ADVISOR.....Samuel L. Hoyt
COUNSEL FOR DEFENSE.....A. W. Merrick
LEGAL ADVISOR FOR COUNSEL.....G. R. Brophy
SHERIFF "ARMED TO THE TEETH".....J. G. Hicks

It was charged that the Defendant, Mr. George Ramsey, machined an axle in such a way as to leave deep score marks with the result that the axle broke in service, resulting in the death of a carload of HOGS.

Inasmuch as this was a criminal action for the People against George Ramsey, the defendant exercised his right to a jury trial, so the following were called and acted as the jury. They were C. F. Marquis, Foreman, M. F. Sayre, F. P. Coffin, R. M. Cherry, G. Hegel, J. K. Haynes.

The defendant, members of the jury and the several witnesses were duly "Sworn at" by the Clerk of Court (Jim Taylor).

The first witness called (S. L. Hoyt) stated to the court that in August 1922 he visited the shop of the defendant, and while there a "blonde" woman came through the shop with the result that the defendant became very nervous and excited so that he allowed the lathe he was operating to "run wild." Photographs of the broken axle were shown as evidence, as well as micrographs and macrographs, of the material to prove that the steel was of the best. The photographs of the fractures proved that the defect started in the fillet.

Another witness was the brakeman (B. T. Perry) who testified that while about his duties on the freight train in the fall of 1925 an accident occurred to a car in which the hogs were being shipped with the result that the hogs died. The counsel for the defense tried to prove that "lard oil" from the hogs trickled down to the axle which was hot and changed the structure of the steel with the result that the axle failed.

The Judge (Chas. M. Hughes, a well known Schenectady lawyer) had quite a time keeping both the district attorney and counsel for the defense from each other and threatened several times to throw them both out of court. His handling of the "trial" made it both very instructive and at the same time amusing.

To try and describe the trial in detail would fill almost a complete issue of TRANSACTIONS as it lasted for 3½ hours. The jury broke all records in deliberating on the case for they reached a verdict of "GUILTY" in 59 seconds. The defendant was placed on probation for one year but has to report to one of the local "CHARITY" organizations each week as to his behavior.

James Taylor.

SOUTHERN TIER GROUP

The regular monthly meeting of the Southern Tier Chapter was held Monday evening, May 23, 1927, at the Century Club, Elmira, N. Y., with about sixty members in attendance. Among those present were delegations from Binghamton, Endicott, Norwich, Painted Post, New York and Athens, Pennsylvania.

At the business session, officers were elected as follows: Chairman, F. W. Taft, Binghamton; Vice-Chairman, M. O. Snyder, Elmira; Secretary-treasurer, W. H. Ogden, Binghamton. At this time a rising vote of thanks was given to the retiring officers for their untiring efforts during the past year to put the Southern Tier Chapter on the map of the American Society for Steel Treating. The results, eighty-two members the first year in a territory without any large cities, certainly speak for themselves and set a high standard for the newly elected officers to maintain. The new officers showed that they are not going to rest on their oars by challenging the Syracuse Chapter to a race, the goal to be one hundred members.

The members of the Chapter voted to hold a picnic meeting some Saturday in June and again challenged the Syracuse Chapter; this time to a baseball game.

The educational feature of the evening was a talk by F. C. Raab of the Brown, Lipe, Chapin Company, Syracuse. By means of slides he illustrated the manner in which automotive differential gears are manufactured. He described the different methods of forging the gears and explained the way in which the steel and the forgings were inspected for metallurgical defects. Mr. Raab also told of his experience with the so-called normal and abnormal steels of the carburizing grades as determined by the McQuaid-Ehn test.

Just before adjournment the chairman read a telegram received by Mr. Baker of the Endicott Forging Company from the Wright Aeronautical Corporation stating that the forgings furnished by the Endicott Company played an important part in the successful flight of Lindbergh.

George D. Johnston.

ST. LOUIS CHAPTER

The 67th regular meeting of the A. S. S. T. St. Louis Chapter was held Tuesday evening, May 24, 1927, at the American Annex Hotel with 98 members and guests present. The attendance was gratifying because of the inclement weather, and it took considerable nerve to brave the rains in this section. After the usual dinner the meeting was called to order by the chairman, after which the minutes were approved and read. No new business was reported.

The Nominating Committee presented the following members who were unanimously elected to serve as officers for the coming year:

W. D. Thompson, Laclede Gas Co., Chairman.

W. E. Remmers, Washington University, Vice-Chairman.

C. G. Werscheid, Crucible Steel Co., Secretary and Treasurer.

Executive Committee:

T. S. Carter, Union Electric Co.

R. N. Pease, Axelson Machine Co.

F. G. White, National Enameling & Stamping Co.
C. B. Swander, Wagner Electric Co.
W. H. Joern, Atlas Steel Co.

The speaker of the evening, Dr. John A. Mathews, Vice-President of the Crucible Steel Co. of America, gave an excellent paper illustrated with lantern slides, the subject being "Iron in Antiquity and Today." This subject is the result of a hobby of Dr. Mathews, and has taken the form of collecting a library of historical books on metallurgy and magnetism, dating from 1540 down to the present day. He gave special reference to the remarkable developments of iron in this country during the past fifty years.

The American Institute of Mining and Metallurgical Engineers and the American Chemical Society also shared in this extraordinary program with us. This paper and the pictures are difficult subjects to be reported and would have to be heard and seen to be appreciated.

This was indeed an entertaining meeting, and all who could not avail themselves of the opportunity missed a treat. There being no further business, Dr. Mathews was given a rising vote of thanks. This being the last meeting of the season, the meeting was adjourned until the first meeting, which will be some time in September. *C. G. Werscheid.*

SYRACUSE CHAPTER

On Wednesday evening, April 20, the monthly meeting of the Syracuse Chapter was held in the Chamber of Commerce Building. Following the usual dinner, served to about 25 members and their guests, the business session was opened by W. R. Frazer, vice-chairman. At the finish of the opening formalities, Mr. Raab, metallurgist for the Brown Lipe Chapin Gear Co. was introduced as the speaker of the evening.

Choosing as his topic, "The Manufacture of Case Hardened Gears," Mr. Raab stated that the time allotted for his talk did not permit of his going into a detailed description of gear manufacture but he could present a few of the interesting difficulties encountered and had brought a set of lantern slides to more clearly show these troubles and to illustrate the methods and results of experiment and field development work that he had performed in endeavoring to overcome these troubles.

The first group of slides illustrated the acid etch test on, first the billets as they came from the forge shop, and on the gears in the progressive stages of forging and rolling. The feature of this part was the showing of the effect of the shape of the ingot mould on the etch pattern of the sheared billets and the manner in which this shape persists even in the forged gear blank. The occurrence and persistence of badly porous centers was shown in similar steps and point was brought out that a billet with a porous centered etch pattern makes a poor ring gear. However, by using round corrugated ingot moulds, the area of the defect can be materially lessened and its outline made quite uniform and free from protruding points. These moulds have produced the best billets of any so far tried. One slide of particular interest showed an etch pattern of a sheared billet with several slits in it. Looking up the history of this billet, it was found that it had cooled in the open,

after forging, while the rest of the heat had been pit cooled and furthermore was entirely satisfactory. It was a revelation to the speaker to find that mild steel would react in this manner to cooling especially so when the hardness of the steel as measured by the Brinell machine remained unaffected.

The second group dealt briefly with the two methods generally used to produce the gear blanks. The old method was to use slabs of the desired thickness and forge the gear circular from this, producing a gear that warped and twisted in treating and showing non-uniform flow lines. The upset method as now practiced produced a gear of quite uniform physicals from tooth to tooth and one quite free from the previously mentioned distortion in treating. The results of suitable laboratory tests, impact in particular, and from actual service showed clearly the superiority of the upset over the slabbed gears. After establishing the principle of flow lines in ring gears, attention was turned to pinions, where it was found that an extra and intermediate step was a necessary addition to the two passes previously used in the forge shop. By forging the pinions in three steps, the passes are less drastic, we give the steel a chance to fill out the die and obtain a pinion of good characteristics with uniform and unbroken flow lines. A few slides followed showing the tendency of the carburized area to follow the flow lines in saw tooth formation.

Broaching the subject of normality, Mr. Raab declared that his concern had been mainly with the relatively fine and coarse grained billets from the forge shop. Variations in the heat treated gears had been traced back to corresponding variations in the grain size of the steel previous to forging. The coarse grained steel machines stringy while the fine grained steel causes the tools to chatter. We had to make different compensations in the bores of gears made from coarse and fine grained billets, approximately 0.06 inch for the former and 0.01 inch for the latter in the size tested. However, the coarse grained steel carburized to a given depth in a shorter time, than the fine grained. Then was presented a series of slides showing photomicrographs representing a large number of experiments performed in an attempt to find a single treatment that would produce similar structures on two pieces from the coarse and the fine grained steel. Variations and combinations of rational and irrational treatments all failed to produce similar structures, in any of the numerous pairs of specimens. The steel used in the above experiment was the regular low carbon 1½ per cent nickel alloy bar stock.

Following the presentation of the slides and lecture, the meeting was thrown open to general discussion, including nickel scab hard spots, analysis of steel used, normality, carburizing methods and many other subjects pertaining to gear industry.

H. Lyon Day.

The regular May meeting of the Syracuse Chapter was held on May 10 with Jerome Strauss as speaker of the evening. The subject of the talk was "Corrosion and Corrosion Prevention."

The speaker first discussed the theories accounting for corrosion. Metals can exist in two states, the molecular and the ionic. When metals are in contact with solution they have a tendency to change from the molecular

to the ionic state. Each metal in the ionic state has a definite electrical potential in normal solutions of its salts. When two metals are in contact in a solution, the metal of the higher potential will cause the metal of the lower potential to go into solution. When the products of electrolysis build up about the electrode, the latter becomes polarized, that is, the reaction ceases. Metals can be so treated that they assume a passive state, that is, when in contact with solution, there is a great resistance to the change from the molecular to the ionic state. Aluminum is one of the prominent metals that can be made passive. When a metal is in contact with solution, oxygen is a corroding agent in that it breaks down the polarization by hydrogen. When the corroding medium is in motion, the corrosion products are constantly removed thus allowing more of the metal to go into solution.

The principles of corrosion prevention follow directly from the theories of corrosion causation. To prevent corrosion, avoid contact of dissimilar metals in an electrolyte, cut down the turbulation of the medium, prevent contact with oxygen.

Few of the common metals are reasonably immune to a fair variety of corroding agents. These are copper, nickel, iron and aluminum. When other substances are added to these metals to increase their strength, their resistance to corrosion is decreased.

The speaker showed a number of slides to illustrate the important points in his talk. *S. P. Peskowitz.*

TRI-CITY CHAPTER

The regular May meeting of the Tri-City Chapter, of the American Society for Steel Treating was held on Thursday, May 26, 1927, at the Davenport Chamber of Commerce. Fifty members attended the dinner and talk by S. O. Bjornberg, consulting engineer, Illinois Tool Co., Chicago, Illinois.

Mr. Bjornberg's talk covered the design and methods of checking milling cutters and hobbs of all varieties. These cutters and hobbs are used extensively in the automotive industry for cutting gears of various types.

Business conducted by the Chapter during the evening consisted of election of officers for the coming year.

The officers elected were:

Chairman, E. H. Sohner, General Manager, International Harvester Co., Farmall Plant, Rock Island, Illinois.

Vice-Chairman, Lt. Col. J. Jenks, Rock Island, Arsenal, Rock Island, Ill.

Secretary-Treasurer, George A. Uhlmeyer, Industrial Engineer, People's Power Company, Moline, Ill.

Executive Committee consists of Fred. Turner, Walworth Mfg. Co., Kewanee, Ill. William Donahoe, Velie Motor Co., Moline, Ill. Chas. F. Scherer, Davenport Machine and Foundry Co., Davenport, Iowa. Howard Rogers, Williams, White & Co., Moline, Ill. Prof. John Fielding, S. U. I., Iowa City, Iowa. Earl Taylor, Yellow Sleeve Valve Engine Works, East Moline, Ill. Mr. Frank Vanek, Rock Island Arsenal, Rock Island, Ill. R. K. Barry, Barry Company, Muscatine, Iowa. E. E. Einfeldt, French &

Hecht, Davenport, Iowa. R. E. McGee, International Harv. Co., Rock Island, Ill.

Plans were also made at the meeting for the annual stag picnic to be held during the middle of June. *G. A. Uhlmeyer.*

WASHINGTON-BALTIMORE CHAPTER

At its last meeting of the season (June 3rd), the Washington-Baltimore Chapter was addressed by Luther Becker, Chief of the Iron and Steel Division of the Bureau of Foreign and Domestic Commerce, who recently returned from a survey of conditions in Europe. The talk was entitled "The Position of the United States in the World's Iron and Steel Industry." In this discussion of the dollars and cents of iron and steel from a world standpoint there was so much data presented that only a few high points can be reported here.

It is somewhat difficult to realize the tremendous power of the iron and steel industry in this country without a comparison of figures for production in this and other countries. It is estimated that the world's capacity of ingot steel production is around 110 million tons, of which the United States accounts for about 56 million tons. The following are figures for other countries:

France	10	million tons
Germany	16 to 18	" "
England	12	" "
Saar Valley	2	" "
Italy	2	" "
Japan	2.5	" "
Belgium	3.5	" "
Luxemburg	2.5	" "
Sweden	0.65	" "
Poland	1.5	" "
Czechoslovakia	1.5	" "

Almost every country has adopted certain rulings (tariffs for instance) to protect its iron and steel industry. In order to stabilize prices of iron and steel a "Continental Steel Entente" was formed by several European countries, Germany, France, Belgium and Luxemburg being the principal members. A certain maximum output was allotted to each country, the members agreeing to pay a fine of $4.00 for each ton produced above the allotted maximum. It seems however, that the power of this coalition has been badly shaken since the termination of the British coal strike and it is most probable that some new agreement will be worked out.

It is interesting to note that Germany is moving forward rapidly as an exporter of steel, while the United States occupies fifth place in the amount of iron and steel exported. The steel exports of this country are equal to about 5 per cent of its total ingot steel production, and its imports to about 1 per cent.

In spite of their small proportion the imports of steel have some effect on prices of steel in this country. The most prominent item in the list of

imported products is that of French high phosphorus cast iron pipe, which is sold here at $4.00 to $8.00 per ton below the price of the domestic product.

It was pointed out by the speaker that British India has a surplus of pig iron amounting to about 375,000 tons, and due to the cheap labor and low cost of assembly of raw materials, can market it at extremely low figures.

The great improvement made in the steel plants in Germany recently, as well as the large size of installations, was emphasized; Mr. Becker mentioned for instance, two blast furnaces each producing 1000 tons of pig iron per day.

It was explained that, beside a rather wide use of labor saving devices, lower wages (which are about 1/3 and 1/4 less than those obtaining in this country), and longer working hours, one principal reason for the lower prices on steel products, as compared with those of this country, is the extensive use of the basic Bessemer or Thomas process.

Because of the great consumption of manganese fear has often been expressed in the past for the future of the world's steel production. The biggest deposits of manganese known so far, are located in Georgia (Russia), British India and Brazil, but a large deposit of 2¼ billion tons (estimated) of manganese ore has been recently uncovered in British South Africa, and is being investigated at the present time on the part of American interests.

Some attention was given to the subject of British supremacy in the exportation of tool and other fine steels and the lack of appreciable export of steels of this class by Sweden, Germany and the United States; the maintenance of warehouse stocks by British Companies was pointed to as a large factor in this situation. Mention was made of the high-carbon cobalt chromium steel razor blades, of Sheffield, England, being shipped to this country in recent months.

The use of large amounts of steel scrap, not only in steelmaking furnaces, but also in blast furnaces, is common European practice.

A. I. Krynitsky.

WORCESTER CHAPTER

The ninth regular meeting of the Worcester Chapter was a "Question Meeting". The first question being

What effect has Molybdenum on steel? (Answered by Paul Porter)

Answer: Molybdenum confers special properties on steel. After heat treating this class of steel can be machined. It's ability to machine readily coupled with increase in strength and hardness makes molybdenum a valuable addition to steel. Cost of molybdenum is twice that of tungsten and it seems more difficult to heat treat and obtain uniform results, than other alloy steels.

Question No. 2. *Can the scleroscope hardness tester be used to determine carbon content of steel?* (Answered by Mr. Herman Klaucke)

Answer: The scleroscope can be used under exact conditions probably to check on carbon content, but different conditions have such a marked effect on the scleroscope reading that the results of such a test will usually be non-uniform. Mass, shape, temperature of hardening heat, method of taking test and etc. all effect the scleroscope hardness.

Question No. 3. *What would be considered a safe diameter for a solid*

carbon pipe tap, i. e., How large can it be made without cracking in hardening? (Answered by Mr. Walker)

Answer: There would be no advantage in using a solid steel tap larger than 4 inches in diameter, but can see no reason why one can not be made. Usual practice is to hollow bore large taps or to use a collapsible tap.

Question No. 4. (a) *What is the best heat treatment for high speed steel?*

(b) *Is it safe to quench high speed steel in water to anneal it? Is this the best way to anneal?* (Answered by Mr. Greenman)

Answer: To properly heat treat high speed steel it is first necessary to have the proper equipment. Use a large furnace with plenty of brick in it, then closely control the atmosphere in the furnace. The tool to be hardened should be preheated to 1600 degrees Fahr. and then brought to 2300 degrees Fahr. very fast. No soaking at the high temperature. The tool should be then quenched in oil followed by drawing up to 1100 degrees Fahr. This should be accomplished very slowly.

(b) The quench annealing treatment is not good practice. This treatment can only be used on steel that has not been previously hardened.

Question No. 5. *What effect has chromium and tungsten on steel?* (Answered by Chester Inman)

Answer: Chromium is used to increase hardness, strength and resistance to corrosion. It is added to steel in the manufacturing process or by plating steel parts. Effect on the critical range is to raise the Ac temperatures and to lower the Ar temperatures. Greatest use of chromium is in tool steel. It is apt to produce a surface decarburization and emphasizes the harmful effect of prolonged heating above the critical range.

The effect of tungsten is to add to the cohesive strength of steel. Low percentage of tungsten used in permanent magnets makes steel very sluggish in heat treating and acts as an obstructing agent in transition of austenite into pearlite. Tungsten is used in large percentages in high speed steel.

In this type of steel tungsten confers the property of red hardness. Ability to retain hardness at a red heat.

Question No. 6. *How can grinding cracks be avoided?* (Answered by Luther Holt)

Answer: Grinding cracks can be avoided by using proper wheel. Wheel should be of the right hardness and kept clean and sharp. When using wheel add plenty of water so as to keep water always in contact with surface being ground; otherwise use a dry wheel and be sure no water gets on the surface being ground. Alloy is more apt to give trouble in grinding than is carbon steel. When grinding alloy steel, it is desirable to use a dry wheel.

Question No. 7. *Can cast iron be heat treated to good advantage?* (Answered by Mr. Counihan)

Answer: It is possible to heat treat cast iron. However, there is no single best heat treatment for cast iron. The proper heat treatment is dependent upon the properties that are desired to be developed, as well as upon the hardness of the metal when cast.

There is considerable difference of opinion as to the exact physical proper-

ties that will be developed by a given heat treatment. This is perhaps due to the fact that the cast irons treated are not always similar and because the soaking period while at heat may have been varied.

In general the heat treatments may be divided into 1. Tempering. 2. Annealing. 3. Hardening.

1. *Tempering to relieve strains.* A by-gone practice was to relieve strains in gray iron castings by aging for several months. A 600 to 700 degree Fahr. temper for two or three hours is equivalent to months of aging. There is no change in the physical properties of the metal.

2. *Annealing.* Annealing is resorted to in most instances to improve the machining qualities of the iron. When speaking of annealing cast iron the popular subject of discussion is whether or not annealing weakens cast iron. The higher the temperature and the longer the metal is held at heat the greater is the weakening effect.

Cast iron may be annealed at 1200 degrees Fahr. for two to four hours without any pronounced evil results. As temperatures of 1300 degrees Fahr. and beyond are approached the loss in strength is accelerated.

Most cast iron with a 260 Brinell hardness or below responds to a 1200 degrees Fahr. anneal for two or four hours. The Brinell reading will drop to about 180, which indicates a free machining cast iron. The drop in tensile and transverse strengths are small. If the Brinell reading in the cast state is below 180, no softening results. Other advantages of a 1200 degrees Fahr. anneal are:

1. Less tendency to warp than at higher temperature.
2. Packing in sand or chips to avoid scaling is unnecessary.
3. The scale is limited to a red oxide powder that may be wiped off.

When the Brinell reading is above 260 to 275 a 1500 to 1600 degrees Fahr. annealing may be necessary to promote free machining. The Brinell reading will drop to about 160. If the tensile of the cast specimens were 30,000 pounds per square inch or above, the tensile will drop to about 23,000 pounds per square inch. However, the lowering of tensile is dependent upon the tensile of the cast metal. If the cast metal had a 23,000 pounds per square inch tensile a three or four hour anneal would lower it to but a slight extent. There are few cast irons that will not be made machinable by a 1600 degrees Fahr. anneal. It is claimed that the following heat treatment will soften white cast iron:

Hold at 1800 degrees Fahr. for 3 hours.
Quench in water.
Anneal 10 to 15 hours at 1300 degrees Fahr.

3. *Hardening.* The temperature at which cast iron hardens when quenched lies between 1400 degrees Fahr. and 1500 degrees Fahr. If quenched below this range, the same results are obtained as though the iron were slowly cooled. As the quenching temperature is raised the hardness is increased. About a 1650 to 1700 degrees Fahr. quench in water will develop a Rockwell reading of C40 to C50. The fracture is a silvery grey and readily distinguished from the fracture of white iron. It is also brittle and readily broken.

Little data is available on the properties of cast iron quenched above 1700 degrees Fahr. In brief, it is hard and has no resistance to shock. In this respect it is much similiar to a tool steel that has been greatly overheated and water quenched.

In closing, it may be mentioned that cast iron that does not harden when quenched from 1475 degrees Fahr. in water, does harden if heated in cyanide or carburizing compound and water quenched from the same temperature.

Question No. 8. *What makes screw stock free cutting? What tests are there to show this machinability?* (Answered by Mr. Milton Fromman)

Answer: There is an age old theory that if a steel contains a high percentage of phosphorus and sulphur, it will be free cutting. Such is not the case. We have run hundreds of analyses and tests on steel all having approximately the same analysis, but with widely different machining qualities. A test was run a short time ago on four steels of the following composition.

	I	II	III	IV
Carbon	.109	.063	.095	.095
Manganese	.348	.257	.211	.312
Phosphorus	.098	.120	.116	.117
Sulphur	.052	.055	.052	.059

Tensile Strength all over 100,000 pounds per square inch

Steels 1 and 2 machined well; 3 fair and 4 poor. Under the microscope all four exhibit the same structure.

Another theory is that the dirtier the steel is the better it will machine. If such is the case, just how are we to determine this dirty steel. The microscope is the only means and even then quite a few samples will need to be prepared before you are sure of just what is meant by dirt of good and bad nature, as it is never evenly distributed. Nut stock is of high sulphur content and about as dirty a steel as you will find and yet that varies greatly in tapping qualities.

A test was made on some nut stock that tapped well against some that tapped very poorly.

	I	II
Carbon	.17	.142
Managanese	.621	.580
Sulphur	.123	.149
Phosphorus	.024	.022

No. 1 was good No. 2 poor

In chemical composition nearly the same. Nothing to show why one should tap good and the other poorly. Here the microscope did show us the reason but only after a dozen or more samples had been prepared, we found silicate inclusions. These acted as an abrasion wearing off the threads of the tap. If those inclusions had been evenly distributed we could have found the trouble, no doubt by high silica in analysis or under the microscope in one

prepared sample. High phosphorus and sulphur are very essential for free machining and perhaps dirt, but I believe the only method of testing a steel for its machining qualities is the practical way, that is trying it out.

Question No. 9. *What substitute can be used for cyanide in a bath case hardening process.* (Answered by Earle Clark)

Answer: The ordinary cyanide baths are as follows:

98% sodium or potassium cyanide—

75% sodium—sodium chloride and sodium carbonate

And varying amounts of sodium cyanide such as 45 or 27 per cent cyanide.

Potasium and sodium cyanide are also used in a powdered form by sprinkling the material on the heated piece of steel and allowing it to melt. There are various combinations of powdered case-hardening compounds on the market.

A liquid bath which does not contain the customary sodium or potassium is that of the Shimer Chemical Company and is called the Shimer Process. An inert bath of equal parts of sodium barium calcium chloride called "Meltite" is used in connection with a coke sponge called Cyrok and made of tar and calcium cyanamid in an electric furnace.

The process is simply melting the inert salts and placing 5 per cent of the Cyrok in a melted container at the bottom of the pot. The bath is active when the evolution of gases and spurting of flames at the top of the bath takes place. The cynamid sponge liberates the cyanide radical uniformly until nearly spent, when the decrease in the evolution of gas shows that the cyrok should be renewed. A greater hardness, bigger per cent of carbon on case and more uniformity is claimed of this process.

Doubtless, there are other methods of producing a case in a molten bath, but the Shimer process is the most widely known.

A recent development, the nitrogenizing process, has been put on the market. A nitride case is produced on the work at a temperature of 950 degrees Fahr. with no quenching. This allows for extremely accurate dimensions, being maintained on the parts.

The nitride case is obtained by breaking up ammonia gas and the nitrogen produces the hardness by penetrating the steel. Special steel containing 1½ per cent aluminum is required and the process required about 80 hours, but many parts that cannot be hardened by ordinary heat treating or carburizing methods may be given a hard wearing surface by this process.

Question No. 10. *What changes occur in heating and cooling steel?* (Answered by Mr. Stumpf)

Answer: This question was answered by use of the dilatometer method of heat treating. It showed at least two things. First, that carbon steel has more initial expansion and less through the critical. Second, alloy steel has less initial expansion and more through the critical range.

—*Carl G. Johnson.*

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